OCS Study
BOEM 2014-616

A Method for the Evaluation of the Relative Environmental Sensitivity and Marine Productivity of the Outer Continental Shelf

Final Report

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Authors

URS Group, Inc.
Normandeau Associates, Inc.
LGL Ecological Research Associates, Inc.
RPS Applied Science Associates, Inc. (dba RPS ASA)

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CONTRIBUTING AUTHORS

Alan Niedoroda, Ph.D. – URS Group, Inc.
Sara Davis – URS Group, Inc.
Marcia Bowen – Normandeau Associates, Inc.
Eric Nestler – Normandeau Associates, Inc.
Jill Rowe – RPS ASA
Richard Balouskus – RPS ASA
Melanie Schroeder – RPS ASA
Benny Gallaway, Ph.D. – LGL Ecological Research Associates, Inc.
Robert Fechhelm, Ph.D. – LGL Ecological Research Associates, Inc.

Acknowledgement: Jeffrey Reidenauer, Ph.D., currently employed by BOEM, was a contributing author as an employee of URS Group, Inc.

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Table of Contents

APPENDIX C: FAUNAL AND HABITAT SELECTION

APPENDIX D: COMPREHENSIVE LIST OF IMPACTS FROM BOEM ACTIVITIES

APPENDIX E: SHORELINE HABITAT DATA USED IN THE RESA

APPENDIX F: SPECIES AND HABITAT SCORES FROM THE RELATIVE ENVIRONMENTAL SENSITIVITY ANALYSIS

Figures

Tables

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

BOEM	Bureau of Ocean Energy Management
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
CALC	California Current broad OCS region
CBS	Chukchi/Beaufort Sea broad OCS region
CO_2	carbon dioxide
CMREC	Coastal and Marine Resources and Ecosystem Classification System
CSA	Continental Shelf Associates, Inc.
DFO	Department of Fisheries and Oceans, now Fisheries and Oceans Canada
DPS	Distinct Population Segments
EBS	East Bering Sea broad OCS region
EFH	Essential Fish Habitat
EGOM	Eastern Gulf of Mexico broad OCS region
EIS	Environmental Impact Statement
ESA	Endangered Species Act
ESI	Environmental Sensitivity Index
EVI	Environmental Vulnerability Index
EVM	Ecological Value Map
FGDC	Federal Geographic Data Committee
GOAK	Gulf of Alaska broad OCS region
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LME	large marine ecosystem
m	meter
MarLIN	Marine Life Information Network
MMS	Minerals Management Service
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
NECS	Northeast Atlantic broad OCS region
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
PA	Planning Area
PBR	Potential Biological Removal
RESA	Relative Environmental Sensitivity Analysis
RPS ASA	RPS Applied Science Associates, Inc. (dba RPS ASA)

SECS	Southeast Atlantic broad OCS region
URS	URS Group, Inc.
USFWS	U.S. Fish and Wildlife Service
VEF	valued ecological features
VMAs	vulnerable marine areas
WAOR	Washington/Oregon broad OCS region
WGOM	Western Gulf of Mexico broad OCS region
YOY	young of the year

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CHAPTER 1: INTRODUCTION

The U.S. Bureau of Energy Management (BOEM)[1] has developed a new method for evaluating the relative environmental sensitivity and marine productivity of the Outer Continental Shelf (OCS). The primary use of this method is to assess the relative ecological sensitivity of the BOEM Planning Areas to the regulated activities of offshore oil and gas development, siting of renewable energy generation and transmission facilities, and in future iterations of the model, the extraction of marine mineral resources (including sand and gravel). A team led by URS Group (URS), with members from Normandeau Associates, RPS Applied Science Associates, Inc. (dba RPS ASA), and LGL Ecological Research Associates, Inc., undertook the development of a new method to evaluate the relative environmental sensitivity of the 26 Planning Areas that cover the OCS. A team led by Continental Shelf Associates (CSA) conducted an earlier study that developed a method for comparing the marine productivity among the OCS Planning Areas (Balcom et al. 2011). The study described in this report, combined with the results of the CSA work, provides a new approach for the BOEM regulation of the OCS.

The purpose of this report is to summarize the Relative Environmental Sensitivity Analysis (RESA) method developed by the URS Study Team and its results. The study consisted of five broad tasks:

1. Evaluate information sources for and approaches to estimating relative environmental sensitivity.
2. Develop and recommend options for replacing or supplementing previous BOEM methodologies.
3. Prepare an interim report and present these findings to BOEM staff and selected experts to choose the most appropriate methodology to conduct the analysis.
4. Conduct the relative environmental sensitivity of the 26 OCS Planning Areas using the approach identified and selected by BOEM.
5. Prepare a final report to document the methodologies and information used in the analysis, outline priority data needs for each of the Planning Areas to improve future analyses, and provide direction on how the analysis could be adapted to assess the environmental cost versus benefit of potential future remediation actions.

The first task consisted of a review of the literature and other documents to find and describe other similar documented relative environmental sensitivity analysis methods (Appendix A).

[1] The agency name changed from the Minerals Management Service (MMS) to the Bureau of Ocean Energy Management Regulation and Enforcement (BOEMRE) in May 2010 and to BOEM on October 1, 2011. References are cited according to the agency name at the time the reference was produced.

This information was used to assess the suitability of previously developed methods to meet the needs of BOEM and to consider how aspects of these previously developed methods (Appendix B) could be adjusted and combined into a new method.

The second task involved developing and evaluating options for the creation of one or more new purpose-built method(s) that would provide a scientifically sound and defensible RESA that would be better suited to the BOEM needs than the previously developed methods.

For the third task, an Interim Report was prepared that described the work of the first two tasks, including a detailed description of the proposed method(s). In developing this report, it was decided that a single comprehensive method relying in large part on quantitative assessments was the most effective use of project resources. The remaining tasks included the detailed development of the new method, the application of this method to all of the BOEM OCS Planning Areas, and the production of a final comprehensive report. This final report is a single comprehensive document covering all aspects of the project. Portions of the Interim Report have been incorporated into the text or appendices so that the complete study is addressed. However, this final report has been organized mainly to describe the new RESA method and to illustrate its use across all of the BOEM-regulated OCS.

1.1. BACKGROUND

Section 18(2)(G) of the Outer Continental Shelf Lands Act of 1953, as amended (OCSLA; 43 U.S.C. § 1331) states that decisions regarding exploration and development will be in part based on consideration of "the relative environmental sensitivity and marine productivity of different areas of the Outer Continental Shelf." Relative environmental sensitivity is not defined in the OCSLA and no method to measure it is provided. Environmental sensitivity is not a commonly applied concept in ecology. In previous BOEM RESA approaches, the term "sensitivity" was interpreted to mean the "vulnerability of…ecological components to the potential impacts" of a proposed project Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE 2010).

BOEM examined the issue of environmental sensitivity most closely during the development of its 5-year oil and gas leasing programs. BOEM had previously used an approach that grouped input data into four model components: coastal habitats, marine habitats, marine fauna, and marine primary productivity. Environmental consequences related to oil and gas leasing were considered for three impact-causing factors: spilled crude oil, anthropogenic sound, and physical disturbance. Climate change information was also included as a factor in the analysis. Data were derived from a variety of reports, publications, and data sources. The model produced sensitivity scores for planning areas that were grouped into four classes: most, more, less, and least sensitive. An even earlier iteration of the BOEM RESA utilized an approach solely based on the National Oceanic and Atmospheric Administration (NOAA) Environmental Sensitivity Index

(ESI) to quantify the sensitivity of three main components of shorelines: geology, biological resources, and services provided to humans (NOAA 2002; CSA 1991). This original approach only considered shoreline impacts from oil spills and did not consider impacts to other ecological features such as fauna, offshore benthic habitats and pelagic environments. The analysis also failed to account for the full suite of BOEM-regulated activities.

The Department of Interior has been litigated by the Center for Biological Diversity, Alaska Wilderness League, and Pacific Environment on the grounds that its environmental sensitivity rankings in the 2007-2012 5-Year Plan were irrational as it only considered shoreline impacts. BOEM's program for oil and gas lease management was remanded to the Secretary of the Department of Interior for revisions. As a result, the environmental sensitivity analysis was expanded in the revised 2007–2012 5-Year Plan to include an assessment of individual ecological components of impacts. This approach combined the potential impacts on vulnerable organisms independent of each other into an index of sensitivity and a ranking of the planning areas. However, this approach did not consider cumulative effects on an ecosystem's ability to resist fundamental or "state" change, also known as "resilience" (Groom et al. 2005). Although assessments based on sensitivity or resilience alone are important, they may provide different and potentially conflicting information about the potential impacts from BOEM-regulated activities.

Therefore, the Study Team has developed an updated approach for BOEM that evaluates the environmental sensitivity of a broad range of marine habitats and fauna in relation to the full suite of BOEM-regulated activities. This report presents a description of the new RESA method together with scoring results. This new method provides a sound foundation and develops a process for analyzing the sensitivity and resilience of the coastal and marine environments that BOEM oversees or that may be affected by BOEM-regulated activities.

1.2. BOEM-REGULATED ACTIVITIES

BOEM is responsible for managing the exploration and development of the nation's offshore resources. BOEM-regulated activities include extraction of domestic oil and gas resources, extraction of marine minerals (including sand and gravel), alternate use of existing oil and gas facilities, and development of renewable energy.

BOEM regulates oil and gas extraction through its 5-year OCS Oil and Natural Gas Leasing Program. The Energy Policy Act of 2005 gave BOEM the authority to regulate renewable energy projects and alternate use of existing oil and gas facilities on the OCS. Alternative energy includes, but is not limited to wind, wave, solar, underwater current, and generation of hydrogen. Alternate uses of existing facilities may include research, education, recreation, or support for offshore operations and facilities.

CHAPTER 2: METHODS

2.1. METHOD DEVELOPMENT

2.1.1 Development Process

The first phase in the development of the new RESA method was to evaluate the existing methods for estimating relative environmental sensitivity and marine productivity, including:

- Previous and current BOEM environmental sensitivity analysis methodologies;
- Peer-reviewed literature of case studies, metrics, and data types used in similar environmental sensitivity analyses; and,
- Other information.

Appendix A contains a summary of the literature review, which included a review of methods used in sensitivity assessments, ecological value determinations, marine (and terrestrial) spatial planning, and potential sources of data and information that could be used in the new RESA method.

The goal of this study was to investigate various environmental sensitivity methods and to recommend options that would meet BOEM's current and future needs. The Study Team discussed the strengths and weaknesses of the current method and from that discussion developed a set of criteria that would form the basis of the method evaluation. Thus, the model developed from the Method Evaluation Criteria should:

- Be scientifically valid, transparent (e.g., methods and inputs used to derive results are made available), and repeatable by other scientists;
- Rely on empirical data where possible;
- Be scalable, or easily expanded to allow the addition of new information and additional data;
- Be universal (i.e., applicable to all planning areas and include impacts from all BOEM missions);
- Reflect climate change and cumulative impacts;
- Be able to meet BOEM's needs and address BOEM's concerns;
- Be straightforward to use with understandable results; and
- Accommodate regulated resources.

The Study Team established the most important criterion is that the method be transparent and repeatable so that other scientists could obtain similar results. The second criterion, to rely on empirical data, where possible, will help ensure transparency and repeatability. Model flexibility and scalability is another important aspect of the selected model. The Study Team envisioned that the selected method would be developed for a practical application for this study, and the level of detail that could be applied would depend on the project schedule and available resources. However, the selected method should be flexible enough to accommodate more detailed or updated data in the future – the “ideal model.” The Study Team termed this flexibility “scalability,” which has several dimensions. Spatial scalability is important because of the differing spatial scales that could be evaluated (such as specific BOEM planning areas compared to groups of planning areas, discussed in Section 2.1.4, below). It is likely that the spatial scale of the input data will differ from the BOEM planning areas; thus the model would need to be able to adjust for this. Additionally, it was determined that the method should be scalable such that when data are available on smaller, more precise spatial scales, they can be properly incorporated. Similarly, it would be impossible to include all species or habitats in the practical method. The Study Team determined that the method needed to be capable of being rerun with additional, more specific data with reliable results. Other criteria reflect the study objectives that the method should encompass all planning areas and BOEM activities and incorporate impacts unrelated to BOEM activities, such as climate change and cumulative impacts. The Study Team recognized the importance of including “regulated resources,” such as Federal and State-listed threatened and endangered species and protected habitats in the model.

The Study Team identified 12 methods as potentially suitable for use in developing a revised RESA method. These methods, and how well each method met the study’s original Method Evaluation Criteria, are described in detail in Appendix B. A table summarizing these 12 methods is also provided in Appendix B. Each evaluation includes a description of the main concept of the approach, input data required, output of the model, suitability of the approach to the aims of the BOEM project, and a summary.

This review of existing methodologies for evaluating environmental sensitivity revealed that no single method provides an ideal solution for BOEM’s current needs for the assessment of Relative Environmental Sensitivity. Although there is considerable overlap in the concepts and approaches proposed by existing methodologies, the scope, objectives, and assessment protocols vary. The assessment protocols were evaluated to identify their strengths and weaknesses. The solution for meeting BOEM’s objectives was to develop a purpose-built method (referred to as the “method” or “model”) that reflects BOEM’s needs and that is based on the strengths of the existing methodologies. To this end, the RESA project developed an analytical method that is applicable to the entire Outer Continental Shelf.

Development of the purpose-built method was guided by BOEM’s objective to evaluate the relative environmental sensitivity and productivity of the 26 OCS planning areas. To meet this objective, a precise definition of “relative environmental sensitivity” was essential, and the following definition was developed by the Study Team:

> *Relative environmental sensitivity incorporates both the vulnerability and resilience of an OCS region's ecological components (i.e., habitats and biota) to the potential impacts of OCS oil and gas and offshore renewable energy activities in the context of existing conditions (e.g., climate change forecast, regulatory status, productivity).*

This definition provides the objectives of the purpose-built method. Criteria were also established to guide the method development. The original Method Evaluation Criteria were modified and developed into the following Method Development Criteria:

- Provides an unbiased comparison of the relative environmental sensitivity of different geographic units (e.g., OCS planning areas or groups of planning areas);
- Is scientifically valid (rigorous and repeatable);
- Reflects the wide range of environmental resources that may be vulnerable to BOEM activities on the OCS;
- Includes potential impact-causing factors associated with BOEM activities on the OCS;
- Is applicable to all OCS planning areas or groups of planning areas (e.g., geographic scale of interest);
- Accounts for the unequal sizes of the planning areas or geographic scale units;
- Is scalable (from practical to ideal);
- Includes productivity, climate change, and cumulative impacts under an ideal application of the model;
- Includes the value of regulated resources;
- Relies on empirical data whenever possible; and,
- Avoids unnecessary complexity and is user-friendly.

Once the objectives and criteria were established, a process was outlined to identify each step in the model development. The first step was to select the model inputs. Model inputs were identified to represent both ecological components (Section 2.1.5 and Section 2.1.6) and potential impact-causing factors related to BOEM-regulated activities (Section 2.1.7).

After the inputs were identified, the next step was to develop the analysis protocol. The analysis protocol includes the model structure and the processes and arithmetic used to assess and aggregate the data; these are the essential workings of the model that determine the influence of model inputs on the results. The details of the analysis protocol are described in Section 2.2.1 through Section 2.2.3.

The next step was to populate the model with data and other information and run a preliminary analysis. Results from numerous preliminary test species and habitats were examined to ensure model responses to each ecological component (both species and habitat) are equivalent. During the model development process, model equations and mechanics were honed to most accurately reflect the sensitivity of all species and habitat types to BOEM impact factors (Section 2.2.4). Following these preliminary tests, a full application of the model was conducted, and the driving factors in the model were identified (Section 2.2.5).

2.1.2 Data Acquisition

Application of the RESA method required a large acquisition of data regarding marine species, marine habitats, oil and gas impacts, renewable energy impacts, and a variety of related subjects. Data needs are unique for each step in the model's application, including impact selection, species selection, habitat selection, and each step in the assessment of relative environmental sensitivity for species and habitats (vulnerability and resilience). Despite such disparate topics covered by each of the aforementioned steps of the RESA method, a similar literature review methodology was conducted for each. Published, peer-reviewed, English language studies (or those that provided English language abstracts) that are indexed in scientific databases were the primary focus; although relevant books, book chapters, government and industry technical reports, websites, and presentations were also used in this application of the method. Sources utilized in each step of the RESA model application are noted within their respective sections and appendices. Many broad, overview government and peer-reviewed documents provided relevant information for various steps in the application of the model, while other documents may have only been relevant to a single portion of the sensitivity scoring model.

2.1.2.1 Database Methods

Project literature was stored and managed in a project database using the EndNote® reference management software. Once references were selected by the Study Team (based on their inclusion into model decisions), bibliographic data for the reference was either downloaded directly to the project database or saved (electronically downloaded in a tagged format or manually entered into a template) for later importation. Standard bibliographic data were collected for each reference (e.g., author, date, title, publisher, volume, pages, reference type). The Uniform Resource Locators (URLs) were also collected for websites or documents accessed online. Copyright status was reviewed for each reference, and where restrictions allowed, the abstract (if available) and full-text copy (in .pdf format) of documents were included in the database.

Subject categories were used to organize the references using custom groups within the database. The keywords and geographic location further categorize the references for sorting and searching. Built-in sorting and search capabilities in EndNote® software enable users to create customized reference categories for data output.

2.1.2.2 Information Sources

The Study Team investigated potential sources of data and information that could be used in this application of the RESA method. Exact types of data needed for the analysis were known and could be searched by keyword and subject. The data search focused on recent, readily-available sources, with data in electronic format, rather than in print. The team began with a review of data sources used in BOEM's 2010 RESA (BOEMRE 2010). A second important source of information was BOEM's various data synthesis projects including the Ecospatial Information database (http://esid.boem.gov/), and the Literature Synthesis for the North and Central Atlantic Ocean (Kaplan ed. 2011). Several members of the Study Team participated in some of these previous efforts and thus had information on the data sources. Other BOEM projects such as the Pacific coast data synthesis and compendium of avian information are still ongoing. The third major source of information was from the Study Team's previous experience and familiarity with data sources from all planning areas. This experience was augmented with web-based data searches using conventional search engines. The data sources were categorized in terms of their ecological component(s) and their relevant geographic extent. Verification of data quality was evaluated based on the source of the documentation (e.g., peer reviewed journal), the recentness of the documentation, and how each study was conducted.

Several hundred data sources were identified (Appendix A). They represent compilations from Federal agencies including NOAA, U.S. Geological Survey, U.S. Army Corps of Engineers, and U.S. Fish and Wildlife Service (USFWS); State agencies such as South Carolina Department of Natural Resources; international collaborations such as the Avian Knowledge Network (eBird) and the International Commission for Conservation of Atlantic Tunas; and non-governmental organizations such as the Nature Conservancy, Census of Marine Life, ReefBase and International Union for Conservation of Nature. Some sources, such as the Multipurpose Marine Cadastre, consolidate a multitude of individual datasets. Additionally, a significant number or articles from peer-reviewed journals were utilized in this application of the RESA model.

2.1.3 Practical vs. Ideal Application of Model

While the iteration of the model conducted by the Study Team involved the practical application of the model, it is important to further discuss the spectrum of "practical" to "ideal."

Scalability addresses prioritization of input data and information. Higher numbers of input parameters representing species or habitats provide a more comprehensive and thorough representation of environmental resources. Similarly, a more detailed consideration of potential impact-causing factors provides better resolution than considering only those factors expected to result in the largest impacts. Nonetheless, high numbers of input parameters and detailed analyses may not be feasible at large spatial scales if data are not available or the required level of effort is not considered to be justifiable. The continuum of possible choices for the amount of input information to include in the model can be envisioned as options along a spectrum from "practical" to "ideal." At the theoretical "ideal" end of the spectrum, all ecological parameters (i.e., all species and habitats in an ecosystem) and all potential impact-causing factors are represented within the model. The "practical" end of the spectrum is less well-defined. It seeks to provide a reasonable balance between comprehensive representation of environmental resources and impacts, and realities of data availability and processing feasibility.

The purpose-built method was designed to be scalable with a range of options along a spectrum from practical to ideal. Within this spectrum, input parameters and impact-causing factors could be prioritized as High, Medium, or Low priority for inclusion in the model. The practical (or programmatic) end of the spectrum would include only the higher priority inputs, and be applicable to large geographic scales that require relatively lower levels of detail and resolution. This is the scale used in the "practical" application of the model, which is referred to as the new RESA method. The new RESA method includes impacts from renewable energy and oil and gas activities. Mineral extraction could be considered in future iterations of the model. The opposite end of the spectrum, the "ideal method", would include High, Medium, and Low priority inputs, and would be applicable to small spatial scales where project-specific data collection can be used to fill data gaps, and the highest level of resolution and detail are required. BOEM envisions that the initial practical version will both satisfy its immediate needs and it will prioritize a framework for the continuing development of more refined versions. In this way, the considerable effort (time, data and cost) that will be needed to complete the "ideal method" can be distributed over time.

Impact-independent modifiers (e.g., climate change, eutrophication, and unregulated impacts) could be included in an ideal application of the model to help fully account for an ecosystem-based approach of assessing impacts of BOEM-regulated activities on the OCS. Impact-independent existing conditions that can be assessed qualitatively or quantitatively to further address relative environmental sensitivity could include overfished species, Essential Fish Habitat area coverage, and expansion of climate change analyses. These would be represented as scaling factors that would modify the final scores to account for the relative enhancements of the sensitivities. A more thorough review of these potential impact-independent modifiers and how they could be incorporated in the ideal application of the model is provided in the project interim report (URS Group et al. 2012). An impact-independent modification was not fully incorporated into the new RESA method because of its reliance on quantitative factors, whenever possible considerable effort will be required to define impact-independent conditions in quantitative terms. A discussion of how these factors could affect the model results is provided in Section 3.3.

2.1.4 Geographic Scale Selection

In the development of the RESA method, the geographic scales that could be addressed by the model were evaluated. Three scales were identified: individual OCS planning area scale, broad OCS regional scale (groupings of OCS planning areas), and ecoregion scale. Ecoregion refers to a geographic region containing distinct bioassemblages and ecosystems that are often associated with specific environmental conditions.

For this new RESA method, the geographic scale used was a placement of OCS planning areas into broad OCS regions, as shown in Figure 1. Species/habitat selection criteria discussed in Sections 2.1.4 and 2.1.5 were applied once in each region. This involved nine broad OCS regions, which incorporate all 26 of the BOEM OCS planning areas, as summarized in Table 1. Most of the broad OCS regions include more than one Planning Area. In the case of the Atlantic coast, the Mid-Atlantic Planning Area was divided into two regions and included in the Northeast and Southeast Continental Shelf regions following the approximate large marine ecosystem (LMEs) boundaries (www.lme.noaa.gov).

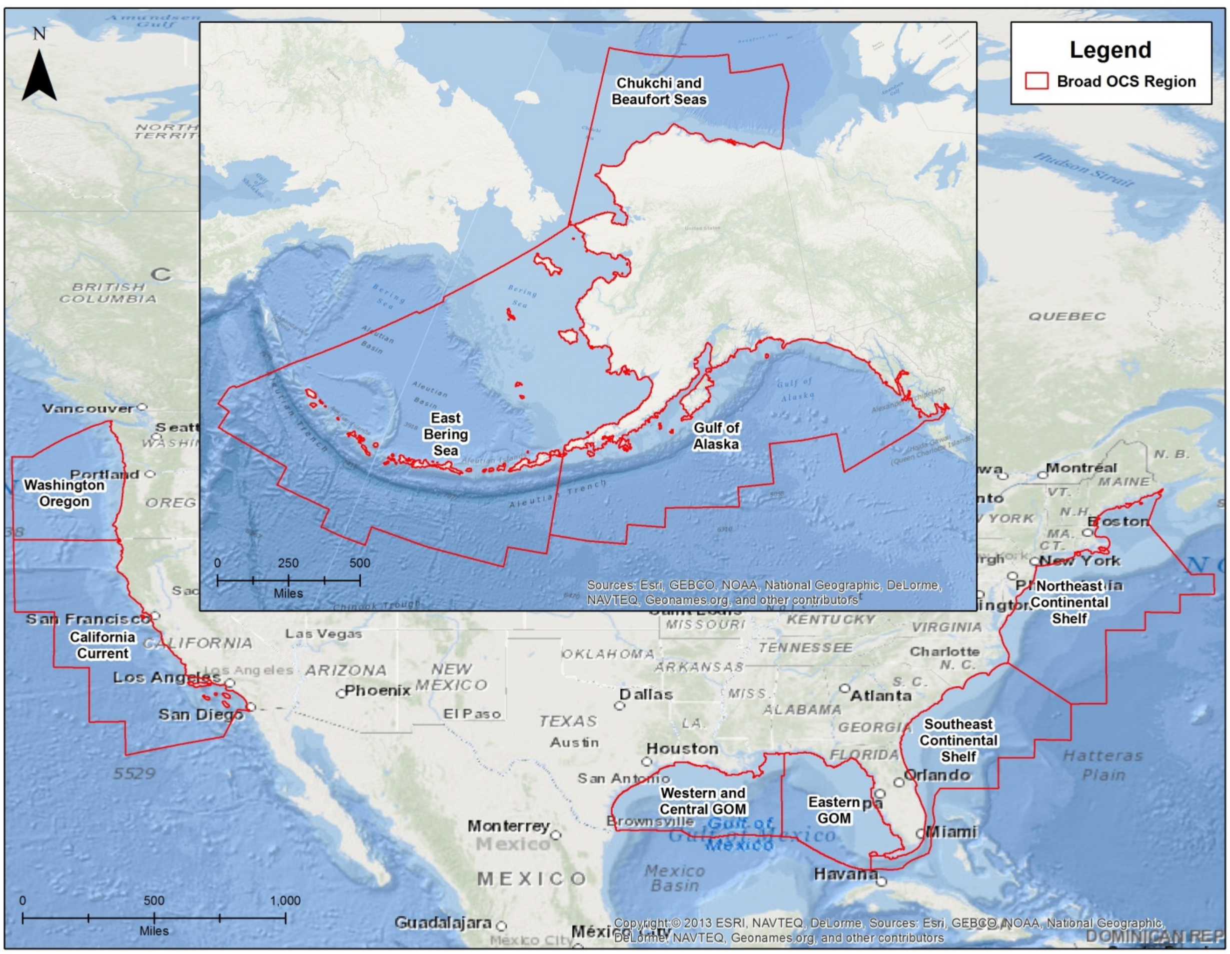

Figure 1: Geographic scale of broad OCS regions used in the new RESA method

Table 1: Twenty-six Broad OCS Regions Used in the RESA Method and Incorporation of Associated BOEM Planning Areas

Broad OCS Region #	Broad OCS Region Name	Broad OCS Region Abbreviation	BOEM Planning Area #	BOEM Planning Area Name
1	Northeast U.S. Continental Shelf	NECS	1	North Atlantic
			2	Mid Atlantic
2	Southeast U.S. Continental Shelf	SECS	2	Mid Atlantic
			3	South Atlantic
			4	Straits of Florida
3	Eastern Gulf of Mexico	EGOM	5	Eastern Gulf of Mexico
4	Western Gulf of Mexico	WGOM	6	Central Gulf of Mexico
			7	Western Gulf of Mexico
5	California Current	CALC	8	Southern California
			9	Central California
			10	Northern California
6	Washington/Oregon	WAOR	11	Washington/Oregon
7	Gulf of Alaska	GOAK	12	Gulf of Alaska
			13	Kodiak
			14	Cook Inlet
			15	Shumagin
8	East Bering Sea	EBS	16	Aleutian Arc
			17	Bowers Basin
			18	Aleutian Basin
			19	Navarin Bay
			20	St. George Basin
			21	North Aleutian Basin
			22	St. Matthew-Hall
			23	Norton Basin
9	Chukchi/Beaufort Sea	CBS	24	Hope Basin
			25	Chukchi Sea
			26	Beaufort Sea

The manner in which planning areas are grouped into the broad OCS regions can affect model resolution and precision. If the groups contain ecologically similar OCS planning areas, resolution and precision can be maintained (i.e., important species/habitats are not overlooked). Some of the planning areas in the Alaska OCS region are ecologically similar and relatively small, and grouping into the OCS region is likely to be most efficient. Conversely, grouping larger OCS planning areas, such as in the North Atlantic and the Mid-Atlantic planning areas, may produce results that are lower in resolution and precision (i.e., locally important species/habitats may be omitted). At the other extreme, higher resolutions could be accomplished by subdividing planning areas into even smaller units of area and aggregating scores to the planning area level. Accordingly, the selection of the individual areas requires considerable effort to minimize the potential for non-uniform environmental sensitivity scoring because it could lead to treating disparate habitats/ecological resources as a single unit. While these considerations were taken into account, the designation of broad OCS regions used in the new RESA represents a first approximation.

2.1.5 Species Selection

In developing the new RESA method, examples of living marine resources were selected to provide representation of the environmental resources that may be vulnerable to BOEM-regulated activities on the OCS. The fundamental unit in the evaluations is the parameter, which is either an individual species or a specific habitat. The parameters are grouped into faunal and habitat ecological components, respectively.

Faunal ecological components (species) have been organized into the following four groups: mammals and sea turtles, birds, fish, and invertebrates. These groups were selected to ensure broad representation across the diversity of organisms that inhabit marine and coastal waters. The two general criteria used in faunal parameter selection were conservation importance and ecological role. For fish and invertebrates, an additional criterion was fisheries importance, which was based primarily on landings data. Table 2 provides the number of species selected for each faunal ecological component of the new RESA method.

Table 2: Number of Species Selected for the New RESA Method

Component Type	Ecological Component	Number of Representative Parameters (per BOEM Broad OCS Region)			
		Conservation Importance	Fisheries Importance	Ecological Role	Total
Species	Mammals and Sea Turtles	4	---	1	5
	Avian	2	---	2	4
	Fish	1	2	1	4
	Invertebrates	---	2	2	4

The number of species in each of the components outlined in Table 2 was determined according to a balance between providing adequate representation while maintaining a practical level of effort in sensitivity assessments and impact scoring. The selection of individual species to represent the environmental sensitivity of each of these ecological components was based on three criteria which are:

1. Conservation Importance – The primary measure used to determine conservation importance is Federal listing status under the Endangered Species Act (National Marine Fisheries Service (NMFS) 2012). One or several species for each Ecological Component, as listed in Table 2, were selected based on the following Conservation priority criteria:
    - Federal endangered species status
    - Federal threatened species status
    - Candidate species for Federal listing
2. Ecological Role – Ecological role for fish and invertebrates was based on two main criteria: high abundance (based on landings or other available information) and importance as a prey species (based on available literature). Species that play a major role in structuring the ecosystem (e.g., keystone species) were also considered.
3. Fisheries Importance (fish and invertebrates) – Fisheries importance was prioritized based on commercial landings by weight data reported by NMFS Fisheries Statistics Division for each broad OCS region. Where possible, species having high commercial landings as well as recreational landings were considered.

A species was only scored once for each broad OCS region. If a species was selected as a representative of the Conservation Importance or the Fisheries Importance categories, it was not considered as a representative for the Ecological Role category.

The application of these criteria in each of the Ecological Components is described in the following subsections.

2.1.5.1 Invertebrates

The following outlined steps were taken to select four invertebrate species for each broad OCS region. In this application of the model, there was no allotment for conservation status for invertebrates. Rationale and references for selected species are provided in Tables C-3 through C-11 in Appendix C.

1. Ecological Role (2 species)
    - For this category, the selection was based on two main criteria: high abundance (based on landings or other available information) and importance as a prey species

(based on available literature). Species that play a major role in structuring the ecosystem were also considered.

- Where possible (i.e., where there were several qualifying species for this category), one pelagic and one benthic species were selected.

2. Fisheries Importance (2 species)

- Species were selected based on commercial landings by weight data from the NMFS Fisheries Statistics Division commercial landings statistics online database. Landings reports were generated for each state in the broad OCS region and then summed. Where possible, 10 years of data (2000-2010) were used to represent the landings.
- The invertebrate species with the highest commercial landings was selected as the first species. An invertebrate species with high commercial landings was selected as the second species. Typically for the second species, the second highest commercially landed species was selected. If either species selected by this process had previously been selected under the Ecological Role category, a species with lower commercial landings (e.g., third, fourth) was selected.
- In the Arctic broad OCS region (CBS in Table 2), important subsistence fishery species were used to represent the fisheries importance category.

2.1.5.2 Fish

The following outlined steps were taken to select four fish species for each broad OCS region. Rationale and references for selected species are provided in Tables C-3 through C-11 in Appendix C.

1. Conservation Importance (1 species)

- The NMFS Office of Protected Resources website was used as the primary source for identifying endangered, threatened, and candidate species, as well as species of concern.

- The order of priority for species selection was as follows: endangered species/Distinct Population Segments (DPSs), threatened species/DPSs, and candidate species/DPSs, as well as species of concern. Candidate species and species of concern were only considered in the event that no endangered or threatened species are present in the broad OCS region.

- For cases where there were multiple species of the same conservation status (e.g., multiple endangered species), the species with the highest International Union for Conservation of Nature (IUCN) Red List status was selected. If species were equal in

IUCN Red List status, the species with the wider distribution within the broad OCS region was selected.

2. Ecological Role (1 species)

    - For this category, the selection was based on two main criteria: high abundance (based on landings or other available information) and importance as a prey species (based on available literature). Important predator species were also considered if they provide forage for other important components of the ecosystem.

    - Where possible, species more widely distributed across the entire broad OCS region were given preference over species restricted to coastal and very nearshore waters.

3. Fisheries Importance (2 species)

    - Species were selected based on commercial landings by weight data from the NMFS Fisheries Statistics Division commercial landings statistics online database. Landings reports were generated for each state in the broad OCS region and then summed. Where possible, 11 years of data (2000-2010) were used to represent the landings.

    - The fish species with the highest commercial landings was selected as the first species, and a fish species with high commercial landings was selected as the second species. Typically, this second species was the one with the second highest commercial landings, with two exceptions:

        - In some cases, a species with lower commercial landings (e.g., third, fourth) was given higher preference if it was also an important recreational species (based on recreational landings data from NMFS).

        - In other cases, a species lower down the commercial landings list (e.g., third, fourth) was selected if either the first or second place commercial landings species were selected for the Ecological Role category.

    - In the Arctic broad OCS region (CBS in Table 2), important subsistence fishery species were used to represent the fisheries importance category.

2.1.5.3 Birds

The bird selection process relied on the best available data available at the time (BOEM's Avian Compendium for the Atlantic OCS was not finalized at the time of the scoring). Avian species selection was based on eBird lists, a database populated by bird watchers' year-round observations and that includes both coastal and pelagic observations. Data from eBird were tabulated to develop estimates of frequency of observations for species using the broad OCS regions. Frequency of observation is used as a proxy for abundance. Rationale and references for selected species are provided in Tables C-3 through C-11 in Appendix C.

Data Reduction

Reliable regional population estimates are not widely available for birds in the broad OCS regions. To select bird species, the eBird list for each broad OCS region was downloaded from the eBird website, using coastal counties when reasonable. The combined observation frequencies (percentage of total eBird checklists reporting a species) from the year 1900 to the present were calculated for each species. The species list was then narrowed down to those species found primarily in saltwater. For example, all birds occurring in the list in the taxonomic sequence following Alcids (e.g., puffins, murres, etc.) were deleted, starting with Columbids (pigeons, doves), because these birds are less likely to be affected by offshore developments. All inland ducks were deleted (whistling-ducks through dabbling ducks, with the exception of Brant), along with Galliformes (grouse, quail, etc.), storks, Ardeids (egrets, herons, etc.), ibis, raptors and Rallids (rails, etc., except for Clapper Rail because it is coastal). While some members of these taxa may be found at times on the coast, most are more common inland. This edited list was sorted from highest to lowest observation frequency. This list was further narrowed to create a “most common saltwater” list of the 50 most frequently observed remaining species. The list was reviewed and any remaining species with strong inland distribution trends were deleted, along with any taxa that were not full species, such as uncertain identifications (e.g., duck sp.) and species combinations (e.g., Sooty/Short-tailed Shearwater). This list included shorebirds, sea ducks, tubenoses, and all other birds likely to be seen on or in saltwater.

Because the majority of bird observations are made from shore, the most common saltwater species list does not fully account for seabird (e.g., tubenoses such as shearwaters, Alcids such as puffins, etc.) abundance. To rectify this shortcoming, one or more separate lists were created. First, a separate Procellariiformes (tubenoses) list was created and the 20 most frequently encountered tubenose species were selected from this list. Additional lists were created for other groups of seabirds as needed (e.g., Alcids) that, depending on the region, might not be equitably represented in the saltwater species list because of their offshore distribution trends. Lists of seabirds (tubenoses, Alcids, etc.) for each broad OCS region were combined to create a list of “seabirds combined” that contained the seabirds (i.e., birds with strong offshore distribution trends) most frequently observed in the region.

1. Conservation Importance (2 species)

    - Species of conservation importance were selected first. The federally listed threatened and endangered species were taken from a master list of federally listed bird species per broad OCS region based on information from the USFWS Endangered Species webpage (http://ecos.fws.gov/tess_public/SpeciesReport.do?groups=B&listingType=L&mapstatus=1). Where possible, species were selected from dissimilar ecological niches, e.g., a beach and an offshore species.

2. Ecological Role (2 species)

    - After the species of Conservation Importance were selected, species were selected for Ecological Role. The most frequently observed species from the "most common saltwater" and from the "seabirds combined" list were chosen based on having ecological roles complementary to those of the species of Conservation Importance.

2.1.5.4 Marine Mammals and Sea Turtles

The following outlined steps were taken to select four species in the sea turtle and marine mammal ecological component for each broad OCS region. Marine mammals and sea turtles were grouped together because no sea turtles occur in the East Bering Sea and Chukchi/Beaufort Sea broad OCS regions, which could bias the results at the relatively low numbers of species being assessed in this application of the model. The two faunal groups were combined because they are more similar to each other than to any other species group. For example, both species groups are highly migratory, air-breathing, and include apex predators. Rationale and references for selected species are provided in Tables C-3 through C-11 in Appendix C.

1. Conservation Importance (4 species)

    - The selection process for marine mammals and sea turtles of Conservation Importance relied heavily on information developed by the NMFS Office of Protected Resources, and species were selected in the following manner. First, a table of all federally listed threatened and endangered species of marine mammals and sea turtles within each broad OCS region was developed, along with each species' status and presence of a corresponding critical habitat. An example is shown below. Four conservation status marine mammal and sea turtle species for each broad OCS region were chosen in the following order, primarily by status: endangered, threatened, proposed threatened, and then candidate.

Broad OCS Region #1 – Northeast U.S. Continental Shelf		
Species	Status (E = Endangered, T = Threatened, PT = Proposed Threatened, C = Candidate)	Critical Habitat
North Atlantic Right Whale	E	yes

    - For marine mammals, the measure of abundance was based on the known prevalence or frequency of sightings from Stock Assessment Reports for each marine mammal species and actual sightings per unit effort data of the species in the region from various offshore projects. For example, blue whales are known to be present, but are rarely sighted, and so would not be chosen first. Other considerations include the amount of information available for the species so that species with the most information are considered over those with little information. For example, there are many studies for right whales foraging habitat, prey species concentrations, satellite tracking, etc., but few for blue or sei whales. Another consideration is whether there is critical habitat delineated within the broad OCS region. Species with critical habitat would be chosen over those that do not have critical habitat (if all other criteria were equal). In some instances, (i.e., sperm whales in the Gulf of Alaska), information like "most frequently sighted large cetacean in the area" was also used to make a selection.

- If there were more than four endangered species in an OCS region (e.g., Washington/Oregon) the process was as follows: species with critical habitat were selected first; then if there is a choice between one or more species, the species with the lowest Potential Biological Removal (PBR) as found in the NMFS Stock Assessment Reports, was selected. For example, in the U.S. Pacific the PBR for fin whales is 16, while the PBR for sperm whales is 1.5 (Carretta et al. 2011), and so sperm whales were selected for the Washington/Oregon OCS.

- For sea turtles, information from NMFS Office of Protected Resources along with Recovery Plans and 5-Year Reviews were used to examine abundance in each broad OCS region. Since all sea turtle species are either endangered or threatened, those species with large numbers of nesting sites in the broad OCS region were selected first.

2. Ecological Role (1 species)

- Selections for marine mammal/sea turtle under the Ecological Role category were accomplished by first creating a table with the most abundant species within each broad OCS region using the "best population estimates" for each marine mammal/sea turtle species from the most current NMFS Stock Assessment Reports. Current population estimates are not available for all species, and therefore those species with estimates would be chosen first as shown for Pacific white sided dolphin (below).

Broad OCS Region #6 – Washington/Oregon		
Species	Stock	Population estimate
Pacific White sided dolphin	CA/OR/WA North and South	26,930

- Some species have multiple stocks with ranges that are sometimes within a broad OCS region and sometimes span multiple areas. For these species, population estimates for single stocks were not used separately, but were rather totaled for all stocks within each broad OCS region using the Stock Assessment Reports. For example, bottlenose dolphins are separated into multiple stocks along the east coast of the U.S. (broad OCS regions #1, Northeast Atlantic [NECS], and #2, Southeast Atlantic [SECS]). The total population estimate for bottlenose dolphins in broad OCS region #1 was calculated by summing each of the separate coastal and offshore stock population estimates when available. Stocks that spanned both broad OCS regions #1 and #2 were included in each broad OCS region population total.

- After the four Conservation Importance species were chosen, the species with the next highest population estimate available was selected for the Ecological Role representative. For example, in broad OCS region #9 (Chukchi/Beaufort Sea), the Alaska stock of ringed seal population estimate is 249,000 seals, and the population estimate for the Chukchi/Beaufort Sea stock of beluga whales is 42,968 (39,258 for Beaufort stock and 3,710 for Chukchi stock). By these numbers alone, the ringed seal would be chosen for the Ecological Role species. However, since the ringed seal status is proposed threatened, that species was chosen under Conservation Importance first. Once the four Conservation Importance species were chosen, the species with the next highest population estimate for this broad OCS region, beluga whale, was selected for the Ecological Role.

2.1.5.5 Final Species Numbers

The number of species selected in each ecological component and broad OCS region is shown in Table 3. Two broad OCS regions Chukchi/Beaufort Sea and East Bering Sea had no federally listed fish species for the conservation importance category, so only three fish species were scored. Five species of marine mammals and sea turtles were scored in each broad OCS region, but the allocation between marine mammals and sea turtles differed, depending on the broad OCS region.

Table 3: Number of Species Scored in Each Broad OCS Region

Broad OCS Region		Birds	Fish	Invertebrates	Marine Mammals and Sea Turtles		TOTAL
					Mammals	Turtles	
Atlantic	NECS	4	4	4	4	1	17
	SECS	4	4	4	3	2	17
Gulf of Mexico	EGOM	4	4	4	3	2	17
	WGOM	4	4	4	2	3	17

Broad OCS Region		Birds	Fish	Invertebrates	Marine Mammals and Sea Turtles		TOTAL
					Mammals	Turtles	
Pacific	CALC	4	4	4	4	1	17
	WAOR	4	4	4	4	1	17
Alaska	CBS	4	3	4	5	---	16
	EBS	4	3	4	5	---	16
	GOAK	4	4	4	5	---	17
TOTAL		**36**	**34**	**36**	**35**	**10**	**151**

2.1.6 Habitat Selection

In developing the new RESA method, the fundamental unit in the evaluations is the parameter, which is either an individual species or a specific habitat. Habitat parameters consist of physical (e.g., substrate types such as boulders and geoforms such as banks or submarine canyons) or biological (e.g., reefs or algal rafts) features that support organisms or communities and have ecologically distinct properties. Habitat parameters were selected to ensure broad and diverse representation in coastal and marine areas within the broad OCS region. They have been organized into three ecological components: shoreline, estuarine, and marine.

Shoreline habitats include ten Shoreline Classes as described in Section 2.2.3. Shoreline sensitivity was developed using the NOAA ESI (NOAA 2002), and thus is treated separately from estuarine and marine habitats.

Estuarine habitats are those benthic and open water areas that are tidally influenced and: (1) have an open-surface connection to the sea, (2) are regularly diluted by freshwater runoff, and (3) exhibit some degree of land enclosure (Federal Geographic Data Committee [FGDC] 2012).

Marine habitats have little or no significant dilution from freshwater except near mouths of estuaries and rivers and include all non-estuarine waters from the coastline to the deep oceans (FGDC 2012). Marine habitats could be further divided into nearshore/offshore and oceanic components. For the new RESA method, nearshore and offshore marine components were combined and include water depths from 0-200 meters (m). Oceanic marine components include water depths exceeding 200 m. Each of these components was further divided into benthic and water column zones.

Estuarine and marine habitat parameters were selected based on their ecological role or importance in terms of their contribution to regional biodiversity and overall productivity. This selection process also took into consideration each of the various components discussed in the FGDC Coastal and Marine Ecological Classification Standard (FGDC 2012) including substrate, geoforms, water column, and biotic characteristics. Table 4 provides the number of estuarine and marine habitat parameters selected for each ecological component in the RESA. A water column or pelagic zone was not included within the marine oceanic component at this time because it was considered to have low potential sensitivity. Depending on the data and resources available, the habitat parameters could be expanded or scaled to include numerous habitat types within each of the zones.

Table 4: Number of Estuarine and Marine Habitats Selected in the RESA Model

Habitat Component	Zone	Number of Habitat Types (per Broad OCS Region)
Estuarine	Benthic	1
	Water Column	1
Marine Nearshore/Offshore (0-200 m deep)	Benthic	2
	Water Column	1
Marine Oceanic (200+ m deep)	Benthic	2
Total Habitats Considered per Broad OCS Region		7

Deciding on the optimum number of habitats per area is difficult and needs to be given considerable attention in the development of the ideal approach. The choice depends on knowledge of the range of habitats within each broad OCS region and the importance of each habitat in comparison to the others with respect to their response to environmental stressors. Habitat parameters selected for each individual broad OSC region should be compared across the regions and, if warranted, the selection modified to minimize the effect of parameter selection on the RESA scoring. To proceed with the new RESA method, the number of habitat parameters per broad OCS region was limited to maintain a balance with the number of species parameters. For this reason, the total number of habitats that were selected for this iteration of the RESA method was limited to seven per broad OCS region.

The number of habitats within each of the components shown in Table 4 was selected to provide a balance between providing adequate representation while maintaining a practical level of effort in sensitivity assessments and impact scoring. Individual habitats were selected primarily based on their ecological role or importance within a broad OCS region. Ecological role included two main considerations: first, the habitat's contribution to biodiversity within a broad OCS region and second, its contribution to overall productivity within the broad OCS region. Additional secondary considerations included a habitat's importance as essential fish habitat for federally managed fish species and its areal coverage within the broad OCS region.

The rationale and references for the selected habitats within each broad OCS region are provided in Tables C-12 through C-20 in Appendix C. For this application of the model, quantitative values for diversity, productivity, or area were either generally not available or inconsistently reported for individual habitats. As a result, the selection process relied primarily on qualitative information provided in synthesis documents and regional fishery management plans to choose individual habitats within a broad OCS region and habitat zone.

2.1.7 Impact Selection

The Study Team compiled an oil and gas impact list using the respective BOEM Programmatic Environmental Impact Statements (EISs) (BOEM 2011), individual project EISs, and notices to lessees and operators. The renewable energy impact list was compiled from the BOEM Programmatic EIS for OCS Alternative Energy (Minerals Management Service (MMS) 2007a), the Cape Wind EIS (Department of Energy (DOE) 2008), and the *Worldwide Synthesis and Analysis of Existing Information Regarding Environmental Effects of Alternative Energy Uses on the Outer Continental Shelf* (MMS 2007b). From the list of impacts for each BOEM activity (Appendix D, Tables D-1 and D-2), a more succinct, refined set of impacts was selected to be part of the RESA method (Appendix D, Table D-3). Each specific impact factor (e.g., habitat disturbance, sound/noise, produced water) was assessed for its comparative relevancy and overall potential impact to species and habitats on the OCS. Only impact factors considered to have the highest potential impacts were included in the RESA. Additionally, several impact factors were combined into a single new analysis impact factor to streamline the assessment. For example, the habitat disturbance, habitat displacement, sediment suspension, and bathymetric changes were all collected into a habitat disturbance impact factor. Impact factors that could not be included by summation (e.g., oil spills) or parsed (e.g., deck drainage) were further assessed in succinct literature reviews. These assessments were used to inform decision making on the final list of assessed impact factors (Appendix D, Table D-3). A complete description of those impacts included in the RESA is found in Appendix D, Table D-3.

2.2. METHOD DESCRIPTION

The RESA of OCS planning areas is conducted through the assessment of three components of the coastal and marine environments of the geographic scale selected: marine species-impact sensitivity, marine habitat-impact sensitivity, and coastal habitat-impact sensitivity.

1. The relative environmental sensitivity of ecologically significant, representative species of each geographic scale unit (e.g., planning area, broad OCS region or ecoregion) is assessed with regard to impacts of BOEM-regulated activities occurring on the OCS. This analysis is conducted through a simple risk assessment model that quantifies both a species' vulnerability and resilience to BOEM-regulated impacts. Species assessed within the model are selected based on a systematic species selection protocol allowing for equal relative sensitivity assessment across the unique geographic scale unit (for details see Section 2.1.4). Results from the species-impact sensitivity model are quantitative

sensitivity scores that may be grouped by species, ecological component, impact, impact factor, and/or geographic scale unit.

2. The relative environmental sensitivity of important and representative marine habitats of each geographic scale unit is assessed with regard to impacts of BOEM-regulated activities occurring on the OCS. This analysis is conducted through a simple risk assessment model that quantifies a marine habitat's vulnerability and resilience to BOEM-regulated impacts. Marine habitats assessed within the model are selected based on a systematic habitat selection protocol allowing for equal relative sensitivity assessment across the unique geographic scale unit, as discussed in Section 2.1.5.6. Results from the marine habitat-impact sensitivity model include quantitative sensitivity scores that may be grouped by habitat, habitat component, impact, impact factor, and/or geographic scale unit.

3. The relative environmental sensitivity of important and representative shoreline habitats of each geographic scale unit is assessed with regard to impacts of BOEM-regulated activities occurring on the OCS. This analysis is conducted through assessment of NOAA's ESI data. The coverage of unique coastal habitats is assessed within each geographic scale unit, and sensitivities to BOEM-regulated activities are determined based on NOAA provided assessments. Only oil spills are assumed to potentially impact coastal habitats within each geographic scale unit.

2.2.1 Species-Impact Sensitivity Model

The species-impact sensitivity model assesses the magnitude of an impact in association with the vulnerability and resilience of each species parameter to that impact through a simple, expandable risk assessment model. Species-impact sensitivity scores are calculated by assessing the relationship between an impact and a species based on Impact Sensitivity attributes. The two principal attributes that assess impact sensitivity are Vulnerability and Resilience. Vulnerability assesses the spatiotemporal overlap of a species with respect to an impact. Resilience assesses a species’ environmental response to an impact. Vulnerability and Resilience attributes are further broken down into more discrete measures of impact sensitivity (sub-attributes) (Table 5).

Table 5: Species- and Habitat-Impact Sensitivity Attribute Terms and Definitions

Term	Definition
Relative Environmental Sensitivity (*i*)	The vulnerability and resilience of a single species/habitat to BOEM-regulated impacts.
Vulnerability (*v*)	Probability that a species/habitat is exposed to a stressor to which it is sensitive (e.g., spatial, temporal overlap).
• Spatial Overlap (s)	Function of the areal extent and the vertical extent of overlap between a species/habitat and an impact.
o Areal Extent (s_a)	Calculated "top-down", or horizontal planar view, overlap of a species/habitat and an Impact.
o Vertical Extent (s_v)	Calculated cross-sectional, or above/below surface depth distribution overlap of a species/habitat and an impact.
• Temporal Overlap (t)	Function of the seasonal overlap of a species and an impact.
Resilience (*r*)	Measure of resistance to disturbance from impact and the speed of return to a pre-impact condition (e.g., susceptibility, recovery).
• Intolerance (n)	Assessment of the degree of negative effect that an impact has on a species/habitat.
• Recovery (c)	*Species Recovery* - Rate (temporal recovery) at and degree (functional recovery) to which a species population is assumed to return to pre-Impact condition after disturbance from an Impact. *Habitat Recovery* - Recovery potential is a measure of the time required for the habitat to return to pre-impact conditions, providing the biological and/or physical characteristics to support marine life or marine biological processes.
Impact Magnitude (*m*)	A summary attribute incorporating Impact Duration, Impact Scale and Cumulative Impacts. It assesses the spatiotemporal extent of an impact factor within an OCS planning area or broad OCS region.
• Impact Duration (m_f)	Temporal scale at which the impact factor most likely occurs.
• Impact Scale (m_s)	Spatial scale at which the impact factor most likely occurs.
• Cumulative Impacts (m_c)	Assessment of existing BOEM-regulated activities in a planning area or broad OCS region of interest relative to other planning areas or broad OCS regions.

The attributes and sub-attributes used to calculate Impact Sensitivity do not measure similar aspects of environmental sensitivity; thus are not overestimating or double-counting impacts. The model is identical across all geographic scale units (e.g., broad OCS regions); thus, the same set of impacts and impact factors are assessed everywhere. The model is completed for each selected species/habitat within a geographic scale unit, producing an individual Impact Sensitivity Score for each BOEM OCS activity for a single selected species/habitat. The species-impact sensitivity model is discussed below. The marine habitat-impact sensitivity model is similar to the marine species-impact sensitivity model and draws upon all of the same concepts; however, with some necessary differences. Those differences are discussed in Section 2.2.2 on the Marine Habitat-Impact Sensitivity Model.

The relative environmental sensitivity of a species to an impact factor is a function of Vulnerability and Resilience.

$$i = v * (10 - r)$$

i = Impact Matrix Sensitivity Score
v = Vulnerability
r = Resilience

In general, a high resilience score means higher resilience to impact, and because a greater r infers greater resilience, it should lead to lower sensitivity. Adding the term of "10 – r" in the equation for Impact Matrix Sensitivity Score effectively flips the "r" value and makes sensitivity properly scale with resilience. In summary, sensitivity to an impact is two-fold. Vulnerability determines the likelihood of exposure to an impact. If something is not vulnerable to an impact, it would not be sensitive to it. Resilience determines what the impact will be when exposure occurs, and how quickly a species may be expected to recover from the impact.

2.2.1.1 Vulnerability

Vulnerability is the product of Spatial Overlap and Temporal Overlap.

$$v = s * t$$

s = Spatial Overlap
t = Temporal Overlap

2.2.1.2 Spatial Overlap

Spatial Overlap is the product of the areal extent and the vertical extent of the species in relation to an impact factor.

$$s = s_a * s_v$$

s_a = areal extent
s_v = vertical extent

Areal extent calculates the "top-down" overlap, or horizontal planar view, of a species and an impact in a geographic scale unit. Greater environmental sensitivity to an impact exists if the entire areal distribution of a species (as opposed to a certain proportion of the areal distribution) overlaps with an impact. Both the species full areal range and the species common areal range is used in the calculation of the areal extent attribute. A species full areal range represents the areal range that the species inhabits at any point in its adult life stage (excluding extralimital strays, etc.). A common areal range of each species parameter represents the probable, or center of aggregation, areal range of the species. The common areal range of each species parameter will often (but not always) be more limited than its full range and will never be greater than the full range. To calculate the areal extent overlap of a species-impact relationship, the mean or center of aggregation of the species areal extent (represented by the mean and one standard deviation to either side of the mean [68.27%]) is considered to inhabit the common areal range, while the remaining individuals of the species within the geographic scale unit (31.73%) are considered to potentially occur at areal extents extending to the species' full areal extent. Impact factor areal ranges are considered in a similar framework. The full areal extent of an impact is set at the areal extent at which the impact factor could potentially affect the geographic scale unit, while the common impact areal extent is set at the range where the impact factor is most likely to occur. The common areal extent is always less than or equal to the extent of the full areal extent. Impact areal extents are unique for each geographic scale unit due to unique bathymetries that determine where BOEM-regulated activities can occur. The proportional overlap of the species' common areal extent and the impact common areal extent is calculated and the proportional overlap of the species' full areal extent and the impact's full areal extent is calculated. Areal extent may be calculated based on range defined by bathymetric contours, or on range defined by distance from shore, whichever data form is more appropriate for the species of interest.

$$s_a = (proportion\ common\ areal\ extent\ overlap * 0.6827) \\ + (proportion\ full\ areal\ extent\ overlap * 0.3173)$$

Vertical extent calculates the "side-view," or cross-section, overlap of a species and the impacts. Greater sensitivity to an impact exists if the entire vertical distribution of a species overlaps with an impact rather than if only a certain proportion of the vertical distribution of a species overlaps with an impact. Vertical extent is always calculated in meters. Because impact factors from BOEM- regulated activities occur both below and above the water line (e.g., oil spill and, for avian species, collisions with above-surface structures, respectively), vertical extents (depth distributions) of species and impacts are considered for both environments. Within the model, the ocean surface is considered at 0 m, with depths below the surface given positive values and distance above the water surface given negative values. Similar to areal extent, vertical extent is broken down into common range (depth distribution at which the species is most commonly found) and full range (depth distribution at which the species may be found with extralimitals excluded). Likewise, impact vertical extents are determined in the same manner as common vertical extents by representing the likely depth distribution at which an impact factor would occur, and full vertical extents representing the depth distribution at which the impact factor could potentially occur.

$$s_v = (proportion\ common\ vertical\ extent\ overlap * 0.6827) \\ + (proportion\ full\ vertical\ extent\ overlap * 0.3173)$$

Bird Flight Regime – Vertical extent calculations are performed in the same manner as the areal extent calculations. In the initial version of the model run, bird species were assumed to be flying for half the time and on the surface for half the time. A more nuanced approach to correcting for flight time regime was developed and implemented using an additional calculation. Unlike other ecological components that are almost always swimming within their vertical extents, many bird species spend a significant amount of time at rest on land or the water surface as well as, in some cases, under the water surface. Though fish, marine mammals, invertebrates, and sea turtles may have defined vertical migrations within their depth distribution, these fluctuations are highly variable by species and are often nuanced in space and time, and therefore difficult to accurately represent in the model framework. Bird species, on the other hand, have a very distinct difference in their vertical distribution because they are usually either flying or they are on the earth's surface (shoreline or water surface). The methodology presented in the vertical extent section above effectively models bird species as always at flight and actively diving in pursuit of food (when applicable). A side effect of this is incorrect and misleading vertical vulnerability scores (s_v). A correction factor is therefore applied to account for the amount of time a species is active (flight/diving) versus at rest. To more accurately model the vulnerability of bird species to impact factors on the OCS, an additional bird-only parameter (Percentage of Time in Flight) was added to the model. Accounting for the amount of time a bird spends flying, as opposed to on the shore or water surface, is important in calculating its vulnerability to impact factors.

Flight Regime Full Vertical Extent (s_{vb})

$$
\begin{aligned}
s_{vb} = {} & (proportion\ full\ vertical\ extent\ overlap * proportion\ of\ time\ in\ flight) \\
& + (proportion\ resting\ vertical\ extent\ overlap \\
& * proportion\ of\ time\ on\ surface)
\end{aligned}
$$

This is repeated for the common vertical range calculation. The vulnerability score for bird species is then calculated using these flight regime-corrected vulnerability scores (Table 6). Species that spend a greater percentage of time in flight are therefore generally more vulnerable to above-surface impact factors.

Table 6: Mean Flying Time Categories for Vulnerability Scoring

Flight Regime (Percent of time in flight)	Modeled Proportion of Time in Flight
Minimal (0-20%)	0.1
Low (21-40%)	0.3
Moderate (41-60%)	0.5
High (61-80%)	0.7
Very High (81-100%)	0.9

Surface-Breathing Species – Obligate surface-breathing mammals and sea turtles spend an increased amount of time at the air/water interface. This makes these species particularly susceptible to near-surface impact factors. To account for this, all obligate surface-breathing species are modeled with a probable vertical extent range of 0 to 15 m.

Areal and Vertical Extent Limits – BOEM OCS planning areas and respective broad OCS regions are fixed in space. Each planning area extends a unique distance out into the OCS region. Each of these regions also has a unique bathymetry. Accounting for physical differences in each geographic scale unit is important in accurately calculating spatial overlap for species and habitats. For the RESA, maximum areal and vertical extents for each OCS broad are determined and input. For each OCS broad region, the maximum depth (vertical extent), the mean distance from shore (areal extent) at which the jurisdictional boundary of the OCS broad region exists, and the mean bathymetry contour at the mean distance from shore (areal extent) at which the jurisdictional boundary of the OCS broad region exists are determined and input. The values serve respectively as maximum vertical and areal extent values for species and habitats. Additionally, minimum values are set for areal extents as -3 meters for bathymetry contours data type and -1 kilometer for distance from shore data type.

2.2.1.3 Temporal Overlap

Temporal Overlap is a function of the co-occurrence, on an annual scale, of a species and the impact factor within a geographic scale unit. This calculation is based on the assumption that all activity impact factors will occur year round. Thus, Temporal Overlap is simply a function of the proportion of months that the species is present in the geographic scale unit.

$$t = \frac{\#\, months\ species\ present\ in\ broad\ OCS\ region}{12}$$

The Vulnerability score (v) calculated through the above steps leads to a value ranging from 0 to 1, with 0 representing no overlap between the species and impact and 1 representing complete spatiotemporal overlap of the species and impact. Species that are not vulnerable to an impact (v=0) are found to have no environmental sensitivity to that impact as they never overlap in space and time. Greater proportional overlap of species/impact interactions leads to potentially greater relative environmental sensitivity for that species-impact interaction.

2.2.1.4 Resilience

Resilience is calculated through three sub-attributes: Intolerance, Recovery and Impact Magnitude. A greater resilience score indicates a species that is more highly resilient to an impact.

$$r = 10 - ((1.2 * n + 1.2 * c + 0.6 * m)/3)$$

Where:
n – Intolerance
c – Recovery
m – Impact Magnitude

In general, scores of “10” for Intolerance, Recovery, and Impact Magnitude indicate the "worst" effect. For instance, an Impact Magnitude of “10” is quite large, while an Impact Magnitude of “2” is relatively small. Therefore, smaller numbers for each of these input parameters indicate more highly resilient species. However, in order for Resilience to semantically make sense, a higher score should indicate higher resilience. Therefore, the equation is as shown above. This issue is due to the ranking systems being inverse, in which a high Intolerance is not favorable while a high Resilience is favorable.

2.2.1.5 Intolerance

Intolerance (*n*) assesses the degree of harm an impact causes a species when an impact factor and an individual of the species directly interact (in the case of habitat disturbance, indirect interactions are also considered). Intolerance is ranked by working through a key (Table 7). Supporting data and documentation are collected from published literature and government documentation. Where supporting documentation does not exist, is incomplete, or is inconclusive, professional judgment may be used to work through the key. As future research becomes available, it will then be possible to update species specific intolerances to impact factors. Upon completing the key (Table 7) and selecting an Intolerance level, a rank is assigned to the Intolerance level (Table 8).

Table 7: Intolerance Key

1a. Biological opinions, EISs, or published literature exist regarding the species (or representative grouping, or proxy species)-impact interaction.	Go to 2
1b. Biological opinions, EISs, or published literature do not exist regarding the species-impact interaction.	Go to 5
2a. Negative effects or the possibility thereof (reduced survival, injury, mortality) have been noted for the species/proxy species.	Go to 3
2b. Negative effects or the possibility thereof (reduced survival, injury, mortality) have not been noted for the species/proxy species.	Negligible
3a. Impact to the individual is from very likely to certain to be lethal or, habitat disturbance from the impact is likely to lead to lethal effects within the individual’s lifetime.	High
3b. Impact to the individual is not from very likely to certain to be lethal.	Go to 4
4a. Impact causes high levels of sub-lethal effects and possible acute mortality to the individual or, in the case of habitat disturbance, impact likely causes sub lethal-effects and may lead to lethal effects within the	Moderate

individual’s lifetime.	
4b. Impact does not cause high levels of sub-lethal effects and possible acute mortality to the individual or, in the case of habitat disturbance, impact likely does not cause sub lethal-effects and will not lead to lethal effects within the individual’s lifetime.	Minor
5a. Negative effects or the possibility thereof (reduced survival, injury, mortality) are likely for the species.	Go to 6
5b. Negative effects or the possibility thereof (reduced survival, injury, mortality) are not likely for the species.	Professional Judgment: Negligible
6a. Lethal effects on individuals are from very likely to certain from the impact, or habitat disturbance impact is likely to lead to lethal effects within the individual’s lifetime.	Professional Judgment: High
6b. Impact likely does not cause from very likely to certain lethal effects on the individual.	Go to 7
7a. Impact likely causes high levels of sub-lethal effects and possible acute mortality to the individual or, in the case of habitat disturbance impact, likely causes sub lethal-effects and may lead to lethal effects within the individual’s lifetime.	Professional Judgment: Moderate
7b. Impact likely does not cause high levels of sub-lethal effects and possible acute mortality to the individual or, in the case of habitat disturbance, impact likely does not cause sub lethal-effects and will not lead to lethal effects within the individual’s lifetime.	Professional Judgment: Minor

Table 8: Intolerance Rank Definitions and Rank Scores

Intolerance Rank	Definition	Rank Score
High/Professional Judgment: High	Impact very likely to cause lethal effects on the individual or in the case of habitat disturbance is likely to lead to lethal effects within the individual's lifetime.	10
Moderate/Professional Judgment: Moderate	Impact causes high levels of sub-lethal effects and possible acute mortality to the individual, or in the case of habitat disturbance impact likely causes sub lethal-effects and may lead to lethal effects within the individual's lifetime.	8
Minor/Professional Judgment: Minor	Impact causes greater than negligible effects to an individual of the species, but less than Moderate levels of effects.	4
Negligible/Professional Judgment: Negligible	No discernible or very minimal negative effects or the possibility thereof exist from the species-impact interaction.	0
Not Applicable	The species is not vulnerable to the impact, therefore intolerance is not assessed. The species is not sensitive to the impact.	0

2.2.1.6 *Recovery*

Recovery (*c*) assesses the rate at which a species population (or sub-population) is able to recover following interaction with an impact factor. Recovery rate is determined through a flow chart modeled in part after the Marine Life Information Network (MarLIN) project (Hiscock and Tyler-Walters 2006). Several aspects of a species' ecology, life history and physiology are considered in concert with the level of intolerance to an impact factor to determine the species recovery. Species that are highly intolerant to an impact factor will inherently have slower recovery rates than another species that is moderately intolerant to that same impact factor. The Recovery rank is determined through a series of if-then statements within the model, presented in the chart below (Figure 2) and defined in Tables 9 and 10.

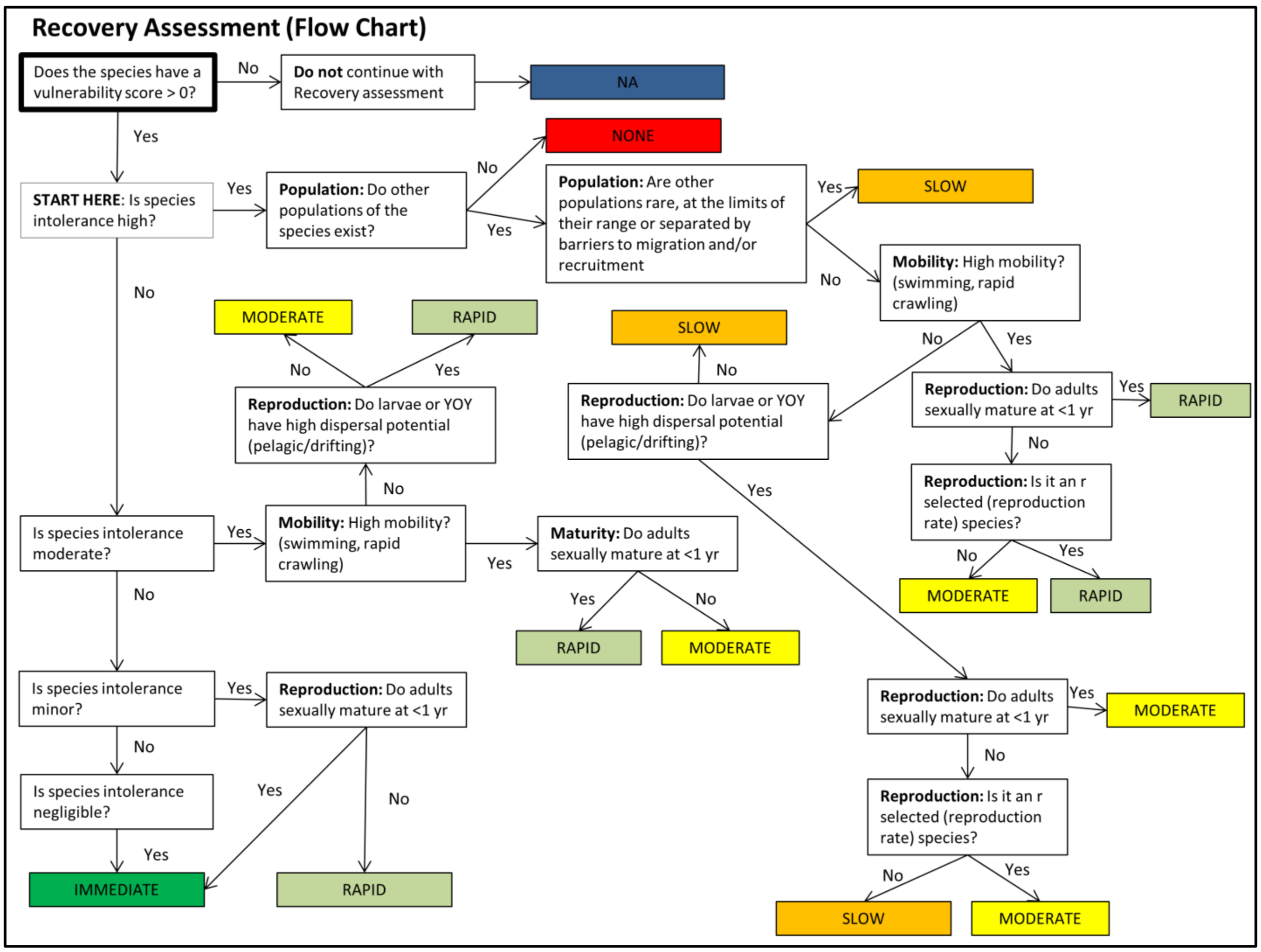

Figure 2: Recovery assessment flow chart (Concepts modeled in part after Hiscock and Tyler-Walters 2006) [YOY is young of year]

Table 9: Recovery Rank Definitions and Rank Scores

Recovery Rank	Definition	Rank Score
Immediate	Full functional recovery occurs within a month.	0
Rapid	Full functional recovery likely to occur in less than 1 year.	2
Moderate	Partial functional recovery likely to occur within 5 years and full functional recovery likely to occur in greater than 10 years.	4
Slow	Partial functional recovery likely to occur within 10 years, full functional recovery may occur in greater than 25 years or never.	8
None	Functional recovery of species will not occur in within the next 50 years.	10
NA	The species is not vulnerable to the impact, therefore recovery is not assessed. The species is not sensitive to the impact.	0

Table 10: Questions Used in the Recovery Flow Chart

Topic	Question	Possible Answers	Reason for Inclusion
a. Regulatory Status	Is the species listed as threatened or vulnerable under the Endangered Species Act (ESA)?	Federal endangered, Federal threatened, or not ESA-listed (candidate species were included as threatened)	Serves as a proxy for rarity of the species. Rarer species are less capable of population-wide recovery after disturbance
b. Population distribution	Is entire population of assessed species found only within the broad OCS region/ Planning Area (PA)? A species that is seasonally endemic is considered endemic.	Yes/No	Species that are endemic to a broad OCS region/PA are incapable of recovering population from adjacent broad OCS regions/PAs and are therefore likely to recover more slowly.
c. Population connectivity	Are populations in adjacent planning areas/broad OCS regions rare, at the limits of their range, or separated by barriers to migration and/or recruitment? Relationship of the species abundance and/or connectivity to that same species in adjacent planning areas/ broad OCS regions. Rarity and limit of range may be assessed by distributional information.	Yes/No	Species capable of re-colonization and cross-breeding from adjacent broad OCS regions/PAs are capable of recovering more quickly from disturbance. Species with high abundances in adjoining broad OCS regions/PAs are capable of recovering more quickly from disturbance.
d. Species mobility	Is species highly mobile (swimming, rapid crawling?) as an adult?	Yes/No	Highly mobile species are inherently more capable of re-colonization and cross-breeding from adjacent broad OCS regions/PAs, resulting in faster recovery rates.
e. Species immobility	Is the species fixed in one place, or in any other way immobile in its adult life stage?	Yes/No	Species that are sessile in adulthood are inherently less capable of re-colonization and cross-breeding from adjacent broad OCS regions/PAs, resulting in slower recovery rates.
f. Age at maturity	At what age (years) is the species capable of reproduction?	Numeric	Species that mature at a younger age are capable of faster recovery as a population. Species that mature at older ages are less capable of fast recovery as a population.

Topic	Question	Possible Answers	Reason for Inclusion
g. Reproduction Rate	What is the species' reproduction rate? Reproduction rate refers to the number and timing of offspring produced by an individual of a species.	High/Low	Species that produce many offspring within a short time period are capable of quicker recolonization and reestablishment of areas where the population had earlier been reduced.
h. Dispersal potential	Do larvae and/or young of year have high dispersal potential (pelagic/drifting/directed)? Dispersal potential refers to the ability of the species to locate new suitable habitat during early life history stages (egg, larvae, juvenile) over a large geographic area.	Yes/No	Species with high dispersion potential are more likely to quickly recolonize an area after a disturbance.

Functional recovery (full and partial) refers to the degree to which a species population returns to pre-impact condition after disturbance from an impact. Due to the granular nature of this assessment, discreet or quantitative definitions (e.g., biomass percent recovery) are not predetermined; rather, full functional recovery refers to the species population return to pre-impact state or equilibrium, and partial functional recovery refers to a species population return to nearly pre-impact equilibrium with some changes in overall biomass occurring.

Rarity and limit of range may be assessed by distributional information, if a species is at the center of its aggregation within a broad OCS region, and/or is not very abundant, then likely the adjacent broad OCS regions\planning areas have rare amounts of that species and/or those individuals will be at the limits of their range. Barriers to migration and/or recruitment may include significant geographical divides, bathymetric divides, other physical bottlenecks, significant ocean fronts, etc.

2.2.1.7 Impact Magnitude ($\boldsymbol{m}$)

The Impact Magnitude attribute assesses the spatiotemporal extent of the impact factor within the broad OCS region as a function of Impact Duration (m_d), Impact Scale (m_s) and Cumulative Impacts (m_c).

$$m = (0.45 * m_d) + (0.45 * m_s) + (0.1 * m_c)$$

Impact Magnitude returns a value ranging from 0 to 10 with 0 representing negligible impact magnitude (e.g., a non-occurring impact factor) and 10 representing the largest possible impact magnitude.

2.2.1.8 Impact Duration (m_d)

The Impact Duration attribute assesses the temporal scale at which the impact factor is likely to occur. Impact Duration ranks the length of time the impact factor occurs when that impact factor takes place (Table 11). For example, a large oil spill is unlikely to occur, but when it occurs the impact may endure for several months; this is the duration that is then assessed with the Impact Duration attribute.

Table 11: Impact Duration Ranks

Impact Duration Rank	Definition	Rank Score
Short-Term	A short-term event whose effects are relaxed almost immediately (minutes to days) (pulse effect).	2
Moderate	A short-term event whose effects are relaxed over a short period of time (weeks to months) (pulse effect).	4
Chronic	A sustained, long-term, or chronic event whose effects are not relaxed (press effect).	8
Permanent	A permanent event that sets a new threshold for some feature of a species' environment (threshold effect).	10

2.2.1.9 Impact Scale (m_S)

The Impact Scale attribute assesses the spatial scale at which the impact factor is likely to occur. The rank reflects an approximation of worst-case spatial scale for each impact factor (Table 12).

Table 12: Impact Scale Ranks

Impact Scale Rank	Definition	Rank Score
Site Specific	A contained impact that occurs only at the location of the impact factor producing structure	1
Small	A minimally dispersed impact factor, potentially occurring over a few square kilometers.	3
Moderate	A moderately dispersed impact factor, potentially occurring between tens and a hundred square kilometers	5
Large	An impact factor that may occur over hundreds of square kilometers of outer continental shelf and coastal areas	10

2.2.1.10 Cumulative Impacts (m_C)

The Cumulative Impacts attribute assesses the level of development (oil and gas or renewable energy) that currently exists within a geographic scale unit (Table 13). Geographic scale units (e.g., broad OCS regions) with greater levels of development have a greater probability of receiving impacts from that development type.

2.2.1.11 Species Sensitivity Score Calculation

With each of the above attributes calculated and ranked, a species' relative environmental sensitivity score is calculated ($i = v * (10-r)$) for each species-impact factor relationship. The potential scores for each relationship is 0 through 10, with 0 representing no sensitivity between the species and the impact factor (which may be the result of either or both vulnerability or resilience) and 10 representing the greatest relative environmental sensitivity possible.

Table 13: Cumulative Impact Ranks

Cumulative Impact Rank	Definition	Rank Score
None	The impact does not currently occur in the broad OCS region/planning area	0
Low	The impact currently occurs in the broad OCS region/planning area in which less than 50% of nationwide OCS development occurs.	5
High	The impact currently occurs in the broad OCS region/planning area in which more than 50% of nationwide OCS development (occurs.	10

2.2.2 Marine Habitat-Impact Sensitivity

The relative environmental sensitivity of marine habitats to BOEM-regulated impact factors is calculated through a modified version of the species-impact sensitivity framework.

Vulnerability is calculated in the same manner as species-impact Vulnerability with the exception that temporal extent is not calculated. Just as impact factors are assumed to occur year round, habitats are assumed to exist within a planning area or broad OCS region year round. This calculates out to full temporal vulnerability, which drops out of the model because it is a multiplier of 1.

> *Areal Vulnerability* is calculated in the same manner as species-impact Vulnerability. Habitat full areal extent and common areal extent are input into the model.
>
> *Vertical Vulnerability* is calculated in the same manner as species-impact Vulnerability. Habitat full vertical extent and common vertical extent are inputs into the model.
>
> *Temporal Vulnerability* is not calculated for habitats in this iteration of the practical model. All habitats are modeled as present year round in their respective broad OCS region. However, the temporal vulnerability parameter is easily added into the marine habitat-impact sensitivity model for future iterations of the model for use with more transient habitats (e.g., floating ice, seasonal upwelling).

Resilience is calculated in the same manner as species-impact Vulnerability.

Intolerance to impact factors is determined through a similar key to the one found in the species-impact sensitivity model (Table 14).

Table 14: Key to Derive Resilience for Habitat Impact Sensitivity

1a. Biological opinions or EISs exist regarding the habitat-impact interaction.	Go to 2
1b. Biological opinions and EISs do not exist regarding the habitat-impact interaction.	Go to 5
2a. Negative effects or the possibility thereof (reduction of biological, physical or biophysical characteristics that support marine life and/or processes) have been noted for the habitat.	Go to 3
2b. Negative effects or the possibility thereof (reduction of biological, physical or biophysical characteristics that support marine life and/or processes) have not been noted for the habitat.	Negligible
3a. Impact causes complete or functionally complete destruction or removal of habitat.	High
3b. Impact does not cause complete or functionally complete destruction or removal of habitat.	Go to 4
4a. Impact causes some destruction/removal of habitat and certain reduction in characteristics that support marine life.	Moderate
4b. Impact does not cause destruction/removal of habitat or likely reduce characteristics that support marine life.	Minor
5a. Negative effects (reduction of biological, physical or biophysical characteristics that support marine life and/or processes) are likely for the habitat.	Go to 6
5b. Negative effects (reduction of biological, physical or biophysical characteristics that support marine life and/or processes) are not likely for the habitat.	Professional Judgment: Negligible
6a. Impact likely causes complete or functionally complete destruction or removal of habitat.	Professional Judgment: High
6b. Impact likely does not cause complete or functionally complete destruction or removal of habitat.	Go to 7
7a. Impact likely causes some destruction/removal of habitat and certain reduction in characteristics that support marine life.	Professional Judgment: Moderate

Some impact factors included in the RESA are not applicable to any habitats selected for analysis. Therefore, the Sound/Noise and Collisions with Above-surface Structures Impact Factors were preset to Not Applicable within the model framework, resulting in habitat sensitivity scores of 0 for these impact factors.

Recovery is assessed in a single step in the habitat-impact sensitivity model. The user is prompted to enter the habitat recovery potential of the habitat being assessed within the geographic scale unit of interest (Table 15). Recovery potential measures the time period required for the habitat to return to its pre-impact state providing the biological and/or physical characteristics that support marine life or marine biological processes. The level of impact from which the habitat is recovering is:

- Living habitats – complete removal/destruction of the habitat from some, but not all, locations within the broad OCS region (potential "reseeding" stock remains). For example, the recovery potential of eelgrass beds is based upon the complete die-off of most eelgrass beds, but assuming some beds survived that could contribute to reseeding other eelgrass beds.

- Static habitats – complete destruction of the biological and/or physical characteristics that the habitat was providing. For example, the pelagic photic zone may be disturbed by an impact (such as an oil spill) such that it is no longer providing the biological and physical characteristics it once was for the support of marine life. The recovery potential of the pelagic photic zone is based on the time frame it would take for that habitat to return to providing those characteristics again.

- Time-varying habitats (living and static) – impact is assumed to occur during the time period when the habitat is present within the broad OCS region.

Table 15: Habitat Recovery Ranks

Habitat Recovery Rank	Definition	Rank Score
Immediate	Recovery likely to occur within days to a month	0
Rapid	Recovery likely to occur within a month to 6 months	2
Moderate	Recovery likely to occur within 6 months to 3 years	4
Slow	Recovery likely to not occur within next 3 years	8
None	Recovery not likely to occur in the foreseeable future (50 years+)	10

Habitat recovery ranks are assigned based on published literature from peer reviewed journal articles, government documentation, and professional judgment.

Impact Magnitude scores for respective impact factors are all identical to their scores from the species-impact sensitivity spreadsheets.

2.2.2.1 Relative Abundance (optional)

The relative coverage/abundance of habitats is assessed for each marine habitat selected for the model. Habitats that have greater coverage within a geographic scale unit (e.g., broad OCS region) are considered to be more representative of the broad OCS region and their relative environmental scores are adjusted upward. Likewise, habitats that are not as common, or have low coverage are not considered as representative of the broad OCS region and their relative environmental sensitivity scores are not adjusted. Three ranks of relative coverage/abundance are ranked within the model: high, moderate, and low. Relative coverage/abundance is assessed respective to individual habitat types; in other words, each rank is defined specific to each marine habitat type. General rank definitions are shown below (Table 16).

Table 16: Habitat Relative Abundance/Coverage Ranks

Relative Abundance/ Coverage Rank	Definition	Rank Score
High	Extensive development/widespread occurrence of marine habitat of interest	9
Moderate	Some/likely occurrence of marine habitat of interest	6
Low	Scattered occurrence of marine habitat of interest	3

2.2.2.2 *Habitat-Impact Sensitivity Score Calculation*

- *Initial Sensitivity Score Calculation*– With each of the above attributes calculated and ranked, a habitat relative environmental sensitivity score is calculated ($i = v * r$) for each habitat-impact factor relationship. The potential scores for each relationship is 0 through 10, with 0 representing no sensitivity between the habitat and the impact factor (which may be the result of vulnerability and/or resilience) and 10 representing the greatest relative environmental sensitivity possible.

- *Abundance or coverage-adjusted sensitivity* – The initial sensitivity score can be adjusted to account for the relative abundance or areal coverage. This may be calculated by multiplying the initial score by the relative abundance or coverage rank. This calculation results in relative environmental sensitivity scores ranging from 0 to 90, with 0 representing no sensitivity between the habitat and the impact factor (which may be the result of low vulnerability, high resilience, or a combination of both low vulnerability and high resilience) and 90 representing the greatest relative environmental sensitivity possible.

2.2.3 Shoreline Habitat Impact Sensitivity Scoring

For the RESA model, the relative sensitivity of shoreline habitats to oil and gas impacts was calculated directly using NOAA's ESI data. The NOAA Technical Memorandum NOS OR&R 11 (*Environmental Sensitivity Index Guidelines Version 3.0, March 2002*) describes the background and development of this data set:

> Shoreline habitats are at risk during spills because of the high likelihood of being directly oiled when floating slicks impact the shoreline. Oil fate and effects vary significantly by shoreline type, and many cleanup methods are shoreline-specific. The concept of mapping coastal environments and ranking them on a scale of relative sensitivity was originated in 1976 for Lower Cook Inlet (Michel et al. 1978). Since that time, the ranking system has been refined and expanded to cover shoreline types for most of North America, Central America, and portions of the Middle East. The ranking system is most developed for sub-arctic, temperate, and tropical zones. However, some shoreline types unique to the Arctic zone, such as peat scarps and eroding tundra scarps, are included in the ranking scheme. The classification scheme has also been modified to include lacustrine and riverine shoreline types (NOAA 1995). The complete list of standard ESI shoreline rankings is composed of categories for four environmental settings: estuarine, lacustrine, riverine, and palustrine.
>
> The classification scheme is based on an understanding of the physical and biological character of the shoreline environment, not just the substrate type and grain size. Relationships among physical processes, substrate type, and associated biota produce specific geomorphic/ecologic shoreline types, sediment transport patterns, and predictable patterns in oil behavior and biological impact. The concepts relating natural factors to the relative sensitivity of coastline, mostly developed in the estuarine setting, were slightly modified for lakes and rivers. The sensitivity ranking is controlled by the following factors:
>
> 1. Relative exposure to wave and tidal energy
>
> 2. Shoreline slope
>
> 3. Substrate type (grain size, mobility, penetration and/or burial, and trafficability)
>
> 4. Biological productivity and sensitivity
>
> All of these factors and first-hand observations from spills were considered when developing the relative ESI rankings for shoreline types. (NOAA 2002)

Table 17 shows the ESI shoreline classifications for the estuarine setting that were used in the RESA model.

The shoreline analysis for the RESA is based on all of the digital ESI shoreline data that was publicly available as of 2012. Polyline shapefiles for states adjacent to the broad OCS regions were available and downloaded from NOAA (2012b). Table E-1 in Appendix E contains a list of the states for which datasets were obtained and the type of dataset(s) available.

Table 17: ESI Shoreline Classifications Used in the RESA Method

ESI Classification	ESI Rank	Shoreline Types
1	1A	Exposed rocky shores
	1B	Exposed, solid man-made structures
	1C	Exposed rocky cliffs with boulder talus base
2	2A	Exposed wave-cut platforms in bedrock, mud, or clay
	2B	Exposed scarps and steep slopes in clay
3	3A	Fine to medium-grained sand beaches
	3B	Scarps and steep slopes in sand
	3C	Tundra cliffs
4	4	Coarse-grained sand beaches
5	5	Mixed sand and gravel beaches
6	6A	Gravel beaches
		Gravel beaches (granules and pebbles)*
	6B	Riprap
		Gravel beaches (cobbles and boulders)*
	6C*	Riprap
7	7	Exposed tidal flats
8	8A	Sheltered scarps in bedrock, mud, or clay
		Sheltered rocky shores (impermeable)*
	8B	Sheltered, solid man-made structures
		Sheltered rocky shores (permeable)*
	8C	Sheltered riprap
	8D	Sheltered rocky rubble shores
	8E	Peat shorelines
9	9A	Sheltered tidal flats
	9B	Vegetated low banks
	9	Hypersaline tidal flats
10	10A	Salt- and brackish-water marshes
	10B	Freshwater marshes
	10C	Swamps
	10D	Scrub-shrub wetlands; mangroves
	10E	Inundated low-lying tundra

* A category or definition that applies only in Southeast Alaska.

For most of the states, the data formats were identical or very similar. However, some datasets were either more recent, more complete, or based on a different attribute table structure than the majority of the data. Incomplete data sets were used since they were the best available data for some states at the time of the evaluation. The differences in the data sets and the ways they were addressed are described in more detail in the subsequent text.

Within each shapefile, some filtering was necessary to be able to compare appropriate portions of the shoreline in the analysis. Segments of line that were designated as riverine were not suitable for this analysis, and were eliminated from the datasets so that all remaining line segments had a designation of ENVIR (Physiographic Region) equal to “E” (Estuarine). For some states, such as Texas, datasets did not have this designation and all data were considered for the analysis.

For the state of Maine, a unique type of shoreline sensitivity data was available called Environmental Vulnerability Index (EVI) data. This is the only dataset currently available from NOAA; however, the spatial format of the data differs slightly from the ESI data. The same ten classifications used in the ESI data were assigned to the EVI data in polygon form, rather than along segments of the coastline. Whenever possible, values from these polygons were assigned to a coastline provided with the EVI dataset. In areas where no polygon overlapped or contacted the shoreline, that length of shoreline was not considered in this scoring process.

To determine the shoreline habitat impact sensitivity score for each OCS region, a four-step process was used. Within each broad OCS region, the individual states’ datasets were merged into a single ESRI® shapefile and the total shoreline length was divided by the total length of each ESI Classification to obtain a percentage of the shoreline in that broad OCS region covered by each ESI Classification. This percentage was then multiplied by the numeric ESI classification to obtain a score for each classification. Finally, these scores were summed and then divided by 100 to obtain a broad OCS region score within a scale of 1 to 10. Table 18 gives an example of the scores and totals for the Eastern Gulf of Mexico broad OCS region. More than 135,000 miles of shoreline were included in this analysis for all broad OCS regions. Similar tables of scores for the other broad OCS regions are available in Tables E-2 through E-11 in Appendix E.

Table 18: Example of Percentage of Shoreline per ESI Classification for the Eastern Gulf of Mexico Broad OCS Region

ESI Class	Total Miles	Percent of Total	Score
1	114.17	0.70	0.70
2	1.84	0.01	0.02
3	663.27	4.06	12.17
4	159.34	0.97	3.90
5	77.67	0.48	2.38
6	145.80	0.89	5.35
7	244.00	1.49	10.45

ESI Class	Total Miles	Percent of Total	Score
8	2,306.21	14.11	112.88
9	123.54	0.76	6.80
10	12,507.98	76.53	765.30
Total	**16,343.84**	**100.00**	**9.20**

2.2.4 Relative Environmental Sensitivity Score

The relative environmental sensitivity of a broad OCS region is the sum of the sensitivities of its component parts. For this analysis, the parts considered included the species-impact sensitivity and the habitat-impact sensitivity (marine and shoreline habitats combined). Each impact sensitivity grouping (species and habitats) was considered individually, and scores were then normalized to produce equal weighting of the groupings in the final, combined, relative environmental sensitivity scores. The steps involved with computing and aggregating the sensitivity scores are described below.

Vulnerability and Resilience scores were first calculated for each individual species or marine habitat (e.g., "Piping Plover" or "Deep/Coldwater Coral"), within each region, and for each impact-causing factor (e.g., "Oil Spill") associated with each BOEM activity (i.e., "oil and gas" and "renewable energy"). Sensitivity was then calculated as a function of Vulnerability and Resilience. Sections 2.2.1 and 2.2.2 describe the methodology for calculating Vulnerability, Resilience, and sensitivity scores at the level of the species or marine habitat and impact interaction. At this point in the processing, there were multiple sensitivity scores for each individual species or habitat (i.e., a separate score for each impact-causing factor).

The sensitivity scores were then summed across the various impact-causing factors to the level of individual parameters (i.e., individual habitats or species). Following that aggregation, the scores were then summed across parameters to components (i.e., habitat groups or species groups such as "marine/benthic" or "birds"). Throughout this process, sensitivity scores were compiled separately for the two BOEM activities (i.e., "oil and gas" and "renewable energy") and for each broad OCS region. These intermediate sensitivity scores at the component level provide valuable information for sensitivity comparisons among regions, and separately for each BOEM activity.

Next, the sensitivity scores for components (i.e., habitat groups or species groups) were normalized so that each of these measures of ecosystem sensitivity would contribute equally to the final scores. Shoreline habitat scores were included with other habitat components, prior to normalizing the habitat sensitivity scores. Section 2.2.3 describes the methodology for calculating sensitivity scores for shoreline habitats (i.e., ESI values).

Normalization of species and habitat scores was accomplished by converting the scores to percentages of the total score, as follows:

$$\text{Normalized Sensitivity} = (\text{Sensitivity}/\text{Total})*100$$

where:

Normalized Sensitivity = the normalized score, as a percentage of the total, for a species or habitat component within a region and BOEM activity;

Sensitivity = the sensitivity score for a component within a region and BOEM activity; and

Total = the total sum of all sensitivity scores (for species or habitat) across regions and BOEM activities.

The normalized species scores and habitat scores were then summed to calculate the relative environmental sensitivity of species and habitats within each broad OCS region to oil and gas and renewable energy impact factors.

Finally, all sensitivity scores were combined (across BOEM activities) into a single value to differentiate the nine broad OCS regions. Normalization of the component scores ensured that the contributions of the environmental sensitivity of the living marine resources and habitats were counted equally in the combined score.

2.2.5 Method Testing and Checking

2.2.5.1 Examination of Driving Factors for RESA Method

The most applicable method to examine driving factors for the new RESA method is referred to as “One-At-A-Time Sensitivity Measures” in Hamby (1994), which is also known as the driving factors method. In this method, six individual variables (model attributes for the purposes of the current model – Vulnerability, Intolerance, Recovery, Impact Duration, Impact Scale, and Cumulative Impacts) are varied or removed one at a time, while keeping the rest of the model input parameters (the remaining model attributes) fixed.

A "one-at-a-time" sensitivity analysis was conducted to assess the contribution of each input variable to the final results of the model. The examination of driving factors was conducted by varying a single attribute while keeping all other attributes fixed. The model was run with five non-varying attributes for each individual "one-at-a-time" measure of a varying attribute and iteratively set at minimum, median, and maximum values to examine the effect of the varying attribute at different sensitivity levels. For example, , the influence of Intolerance on model results was tested by iteratively increasing the Intolerance rank while keeping all of the static attribute values the same. This allowed the influence of Intolerance under these model conditions (Low Vulnerability and High Resilience) to be examined. Two measures of model sensitivity to each attribute were assessed, including the difference in final species RESA score per increasing level of the varying attribute (numeric intervals of 0.1 for Vulnerability and categorical level increases for Resilience attributes, Table 19), and the difference in the final species RESA score between the minimum possible value and maximum possible values for an attribute (Table 20). In the case of the Intolerance example, one can assess the difference in the final species RESA score per change in Intolerance interval (which is—negligible, minor, moderate, high; Table 19) and the maximum difference in the final species RESA score from varying the Intolerance attribute (e.g., the difference in final score with Intolerance set at its minimum rank and at its maximum rank).

For Tables 19 and 20, within the red/orange/yellow/green color gradient, red represents varying attributes (rows) that alter the final RESA score most significantly per change in interval of that attribute under various model conditions (columns), while green colors represent varying attributes (rows) that alter the final RESA score least significantly per change in interval of that attribute under various model conditions (columns).

In Table 19, the rows represent the attributes that are varied to test their influence on the final species RESA score. Columns represent different static model conditions that can be used to explore the influence of each varying attribute. The model was run with five of the six input attributes (Vulnerability, Intolerance, Recovery, Impact Duration, Impact Scale, Cumulative Impacts) held at single value (alternately low, moderate, and high) while the sixth attribute was varied to determine its influence on the final sensitivity score.

Table 19: Difference in the Final Species RESA Scores per Change in Interval per Attribute

Varying Attribute	Low Res.	Moderate Res.	High Res.	Low Vul./ Low Res.	Low Vul./ Moderate Res.	Low Vul./ High Res.	High Vul./ Low Res.	High Vul./ Moderate Res.	High Vul./ High Res.
Vulnerability	1	0.393	0.027	na	na	na	na	na	na
Intolerance	na	na	na	0.16	0.16	0.16	1.6	1.6	1.6
Recovery	na	na	na	0.08	0.08	0.08	0.8	0.8	0.8
Impact Duration	na	na	na	0.018	0.018	0.018	0.18	0.18	0.18
Impact Scale	na	na	na	0.018	0.018	0.018	0.18	0.18	0.18
Cumulative Impacts	na	na	na	0.01	0.01	0.01	0.1	0.1	0.1

na = not applicable

Note: color coding is described in the text

Table 20: Maximum Difference in Final Species RESA Scores per Attribute

Varying Attribute	Low Res.	Moderate Res.	High Res.	Low Vul./ Low Res.	Low Vul./ Moderate Res.	Low Vul./ High Res.	High Vul./ Low Res.	High Vul./ Moderate Res.	High Vul./ High Res.
Vulnerability	10	3.93	0.27	na	na	na	na	na	na
Intolerance	na	na	na	0.4	0.4	0.4	4	4	4
Recovery	na	na	na	0.4	0.4	0.4	4	4	4
Impact Duration	na	na	na	0.072	0.072	0.072	0.72	0.72	0.72
Impact Scale	na	na	na	0.081	0.081	0.081	0.81	0.81	0.81
Cumulative Impacts	na	na	na	0.02	0.02	0.02	0.2	0.2	0.2

na = not applicable

Note: color coding is described in the text

Each attribute had a specific interval of change for this driving factors analysis. For instance, since the range of possible values for the Vulnerability attribute is 0 to 1 (with 1 as complete spatiotemporal overlap between species and impact), the interval of change for Vulnerability is 0.1. Therefore, to test the influence of Vulnerability on final species RESA score, all five other attributes are held static and Vulnerability is altered by 0.1. The interval of change for Resilience attributes is rank (e.g., minimal, moderate, high). Therefore, to test the influence of Resilience on final species RESA score, all five other attributes are held static and resilience attributes are altered by one rank (e.g., changed from minimal to moderate). In general, the larger number results (shown in red) in Table 19 indicate a greater influence of that varying attribute on the final RESA scores.

2.2.5.2 Driving Factors Analysis: Intolerance

The following text provides an explanation of this driving factors analysis including a walkthrough of varying Intolerance (row 2 in Table 19). To determine the difference in final species RESA scores under different static model conditions for which the Intolerance attribute is responsible, the Intolerance score was iteratively increased in categorical ranks (negligible, minimal, moderate, high) while all other model attributes remained fixed. This iterative process was repeated under various fixed model conditions represented by the columns within Table 19. As an example, for the "Low Vulnerability/Low Resilience" static model condition (fifth column in Table 19), all model attributes were set to low Vulnerability and low Resilience values except Intolerance, the attribute being varied for this particular test. Then when the Intolerance attribute was set to its lowest rank (negligible), the final RESA score was recorded. When the Intolerance attribute was then set to its next highest rank (minimal) with the other attributes remaining at their "Low Vulnerability/Low Resilience" values, a new final RESA score was recorded. This process was repeated for the other two Intolerance categorical ranks (moderate and high), or interval changes. Therefore, Table 19 (column 5, row 2) provides the mean difference in the final RESA score for each interval change in Intolerance under "Low Vulnerability/Low Resilience" model conditions. This process was then repeated for numerous static model conditions, such as “Low Vulnerability/Moderate Resilience” model conditions (column 6, row 2 in Table 19).

2.2.5.3 Driving factors Analysis: Species Impact Sensitivity

Table 20 provides the difference in the final species RESA score between the minimum possible value and maximum possible values for an attribute. This indicates the maximum effect any individual attribute can have on the final species RESA score. As in Table 19, the columns represent different static model conditions that can be used to explore the influence of each varying attribute. Larger numbers indicate greater influence in RESA scores.

The examination of driving factors exposes several facts of the species-impact sensitivity model. Most importantly, when a species has low resilience to an impact factor, the vulnerability of that species is a strong contributor to the magnitude of the final sensitivity score. Among the Resilience attributes, Intolerance and Recovery are the most critical to determining the sensitivity of the species. The one-at-a-time sensitivity model results indicate that no single Resilience attribute contributes disproportionately to the final sensitivity score. Only Vulnerability can produce an order of magnitude difference in the final score. This is acceptable because the sensitivity score of a species that is not vulnerable to an impact, no matter how low its resilience to that impact, should remain low because the species and impact will never interact in space and time.

An examination of driving factors was not conducted expressly for the habitat-impact sensitivity framework. However, results for the pre-abundance sensitivity score would be nearly identical to the species results shown in Tables 19 and 20. The only large difference would be found in the influence of the relative abundance/coverage multiplier, which would have very direct, substantial effects on the final sensitivity score as it is simply a multiplier of the result of the sensitivity score.

2.2.5.4 Method Error Checking

Compilation of data and scoring for each species or habitat in each broad OCS region was done in Microsoft® Excel (see Section 2.2). Data entered into each spreadsheet was checked by the analyst who compiled the data. Species and habitat data inputs and scoring decisions (Intolerance and Recovery ranks) then received a quality control check by independent reviewers on the Study Team.

After scoring in Excel, data were managed using SAS® system software (Version 9.1.3). SAS® (originally "Statistical Analysis System" by SAS Institute Inc.) is a software system used for data handling tasks that are accomplished through a programming interface. SAS® programs were developed to compile the raw RESA scores, and to perform data checking and model assessment routines. The use of programming allowed for the consistent and efficient processing of large numbers of data files (i.e., 215 Excel files – 151 for species, 63 for habitats, and 1 for ESI). RESA data were run through an iterative checking process, in which errors were identified and corrected, and updated spreadsheets were then run once again through the checking procedures until no errors were detected. Data checking and model assessment outputs included data tabulations and listings to identify errors in the scoring data and driving factors contributing to sensitivity scores. As a result of this process, data entry errors that were difficult to detect in the initial quality control review, were identified and corrected. Model adjustments were also made in cases where it was discovered that particular attributes were not adequately or appropriately contributing to the vulnerability or resilience scores. Given the large amount of data input to the model by a number of different researchers, this error checking and model assessment were essential to ensuring data quality.

CHAPTER 3: ENVIRONMENTAL SENSITIVITY SCORES FOR BROAD OCS REGIONS

3.1. Results of the Relative Environmental Sensitivity Analysis (RESA)

The RESA method has been used to evaluate the relative environmental sensitivity of the nine broad OCS regions (Table 1) according to the methods, assumptions, and simplifications described in Section 2.0. The RESA results are presented and discussed below, followed by an examination of the how the individual species and habitat parameters contributed individually to the sensitivity score. This analysis of the details of the scoring process is provided to enhance the understanding of the species and habitats that most affect the final relative sensitivity scores, as well as the importance of the parameter selection process and inputs that are needed to express vulnerability and resilience.

3.1.1 Results of the Analysis

Relative environmental sensitivity scores were calculated for each habitat and species selected (Section 2.1.5 and Appendix C) for each of nine broad OCS regions. These scores form the foundation of the final sensitivity score. As discussed in Section 2.2.4, the scores for habitat and species were normalized prior to combining them, so that each contributes equally (maximum of 100 for all broad OCS regions) to the total score (200 for each BOEM activity). Table 21 and Figure 3 present the normalized habitat and species scores, the total for each BOEM activity, and the total for the broad OCS region (BOEM activities combined).

In terms of oil and gas activity, the Southeastern U.S. and Gulf of Mexico broad OCS regions scored highest, followed by the Northeastern U.S. and East Bering Sea. The Pacific and Gulf of Alaska broad OCS regions had moderate scores, and Chukchi/Beaufort Sea broad OCS region had the lowest score. In terms of renewable energy, the Southeastern U.S. broad OCS region had the highest sensitivity score. The Eastern Gulf had the second highest score, followed by the Western Gulf and Northeast U.S. The Alaskan and Pacific broad OCS regions scored lowest.

In every case, oil and gas sensitivity scores were substantially higher than those for renewable energy. This reflects the more extensive range of oil and gas activities that extends from shallow into deep water (several thousands of feet deep) offshore, compared to the narrower bathymetric range of renewable energy activities that are limited to relatively shallow nearshore waters (few hundreds of feet deep).

When scores are combined for the two types of BOEM activities, the Southeastern U.S. broad OCS region scored highest, followed by Eastern Gulf of Mexico and Western Gulf of Mexico. The Northeastern U.S. broad OCS region had a moderate score and the Alaskan and Pacific broad OCS regions scored lowest. The high Southeastern U.S. scores are reasonable because scoring included both species and habitats with high sensitivity, such as Florida manatee, Atlantic sturgeon, and Sabellariid worm reefs.

Table 21: Normalized Species and Habitat Scores for Each Broad OCS Region and BOEM Activity

Broad OCS Region		Oil and Gas			Renewable Energy			TOTAL
		Habitat	Species	Subtotal	Habitat	Species	Subtotal	
Atlantic	**NECS**	7.8	9.3	17.1	2.6	2.8	5.4	**22.5**
	SECS	10.0	9.5	19.6	6.4	3.7	10.1	**29.7**
Gulf of Mexico	**EGOM**	9.8	10.1	19.9	4.0	3.3	7.3	**27.1**
	WGOM	9.9	9.9	19.8	3.2	2.8	5.9	**25.7**
Pacific	**CALC**	7.8	8.0	15.7	2.1	1.6	3.7	**19.5**
	WAOR	6.7	7.8	14.5	2.4	1.3	3.7	**18.2**
Alaska	**CBS**	6.1	6.9	13.1	1.9	2.1	4.0	**17.1**
	EBS	7.6	8.6	16.2	2.0	2.1	4.1	**20.3**
	GOAK	6.6	8.3	15.0	3.0	1.9	4.8	**19.8**

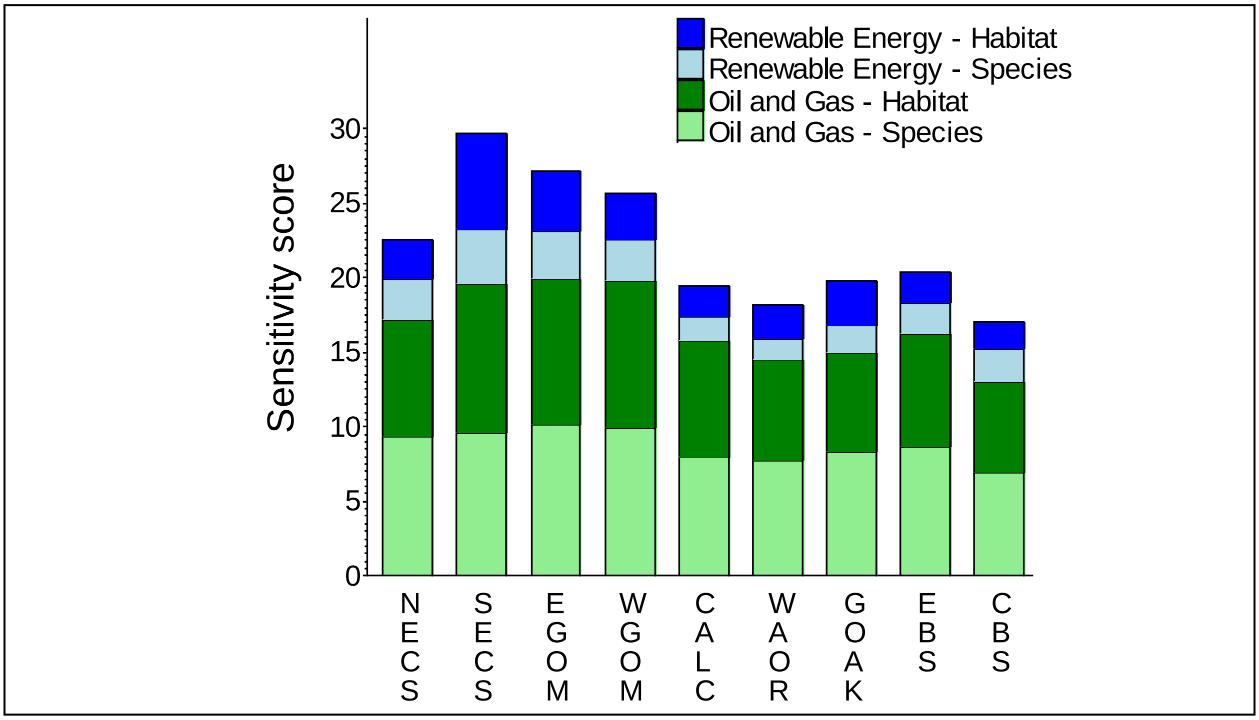

Figure 3: Aggregated sensitivity scores for each broad OCS region by BOEM activity

The relatively high sensitivity score for renewable energy for the Southeastern U.S. was unexpected. Sensitive shallow water habitats such as Sabellariid reefs and submerged aquatic vegetation in the Southeastern U.S. region would be vulnerable to impacts from nearshore activities for renewable energy, and would be slow to recover, increasing the final sensitivity score for that region.

The Chukchi/Beaufort Sea region had the lowest combined sensitivity score, a result of low species and habitat scores. The low species score was in part a result of the lack of federally listed fish species, which are included in the conservation importance criterion. Only three species of fish were scored (Section 2.1.5.2), compared to four for most other areas (the East Bering Sea also had only three species of fish scored). However, even if the species scores are scaled up to 16 species, Chukchi/Beaufort Sea still ranks the lowest for oil and gas and among the lowest for renewable energy. The species that were scored included some moderately high-scoring species such as Baltic macoma clam, polar bear, and spectacled eider (See Section 3.2.1), but most of the remaining species had relatively low scores because they were not present year-round (reducing their vulnerability) or due to their high resilience to change. Some of the habitats (e.g., deep/coldwater coral) had very little spatial overlap with impacting factors, resulting in low vulnerability and therefore low sensitivity. In addition, the habitats selected for analysis (Section 2.1.6) did not score highly (see Table F-2 in Appendix F).

The results allow for comparison of sensitivity provided by both habitats and species among the broad OCS regions. The scale of these results is dimensionless and relative. For instance, an oil and gas score that is three times that of a renewable energy score does not mean that the region is three times more sensitive. Instead, what it means is that that region is relatively more sensitive to oil and gas development than to renewable energy. Because all regions are assessed in the same, objective manner, all relative sensitivity scores are comparable across all regions.

3.1.2 Comparison with the Previous BOEM Evaluation

Results from the RESA (oil and gas and renewable energy) are compared with those developed by BOEM for the 2007-2012 planning study (BOEMRE 2010) in Table 22. The previous BOEM analysis was limited to oil and gas development impacts.

While the 2010 method had more geographic detail because it was based on BOEM planning areas rather than broad OCS regions, the results were comparable in most cases. In all cases, with the exception of the Mid-Atlantic planning area, individual OCS planning areas are entirely contained within individual broad OCS regions in this application of the model. Therefore, in all areas except for the Mid-Atlantic (which was equally distributed between the NECS and SECS broad OCS regions, Table 1) the relative environmental sensitivity score from the broad OCS region may be used directly to represent the planning areas contained entirely within it. This allows for direct comparisons with the previous BOEM study. For the Mid-Atlantic planning area, its respective broad OCS region scores must be averaged to get a comparable “planning area only score.” This corrected “planning area only score” is represented in Table 22.

Table 22: Comparison of Relative Environmental Sensitivity Results with Those Developed in BOEMRE 2010[1]

Broad OCS Region	Broad OCS Region Name	Broad OCS Region Abbreviation	Oil and Gas	Renewable Energy	Total[1]	BOEM Planning Area	BOEM Planning Area Name	Sensitivity based on BOEMRE 2010 (Results from Table 8)[1]
		NECS	17.1	5.4	22.5	1	North Atlantic	Less Sensitive
1	Northeast U.S. Continental Shelf	NECS	18.4	7.8	26.2	2	Mid Atlantic	Most Sensitive
		SECS	18.4	7.8	26.2	2	Mid Atlantic	Most Sensitive
		SECS	19.6	10.1	29.7	3	South Atlantic	Most Sensitive
2	Southeast U.S. Continental Shelf	SECS	19.6	10.1	29.7	4	Straits of Florida	More Sensitive
3	Eastern Gulf of Mexico	EGOM	19.9	7.3	27.1	5	Eastern Gulf of Mexico	Most Sensitive
		WGOM	19.8	5.9	25.7	6	Central Gulf of Mexico	Most Sensitive
4	Western Gulf of Mexico	WGOM	19.8	5.9	25.7	7	Western Gulf of Mexico	More Sensitive
		CALC	15.7	3.7	19.5	8	Southern California	Less Sensitive
		CALC	15.7	3.7	19.5	9	Central California	Less Sensitive
5	California Current	CALC	15.7	3.7	19.5	10	Northern California	Less Sensitive
6	Washington/ Oregon	WAOR	14.5	3.7	18.2	11	Washington/Orego n	More Sensitive
		GOAK	15	4.8	19.8	12	Gulf of Alaska	Less Sensitive
		GOAK	15	4.8	19.8	13	Kodiak	Less Sensitive
		GOAK	15	4.8	19.8	14	Cook Inlet	Less Sensitive
7	Gulf of Alaska	GOAK	15	4.8	19.8	15	Shumagin	Less Sensitive
		EBS	16.2	4.1	20.3	16	Aleutian Arc	Least Sensitive
		EBS	16.2	4.1	20.3	17	Bowers Basin	Least Sensitive
		EBS	16.2	4.1	20.3	18	Aleutian Basin	Least Sensitive
		EBS	16.2	4.1	20.3	19	Navarin Bay	Least Sensitive
		EBS	16.2	4.1	20.3	20	St. George Basin	Less Sensitive
		EBS	16.2	4.1	20.3	21	North Aleutian Basin	Less Sensitive
8	East Bering Sea	EBS	16.2	4.1	20.3	22	St. Matthew-Hall	More Sensitive

Broad OCS Region	Broad OCS Region Name	Broad OCS Region Abbreviation	Oil and Gas	Renewable Energy	Total[1]	BOEM Planning Area	BOEM Planning Area Name	Sensitivity based on BOEMRE 2010 (Results from Table 8)[1]
		EBS	16.2	4.1	20.3	23	Norton Basin	More Sensitive
9	Chukchi/ Beaufort Sea	CBS	13.1	4	17.1	24	Hope Basin	More Sensitive
		CBS	13.1	4	17.1	25	Chukchi Sea	Less Sensitive
		CBS	13.1	4	17.1	26	Beaufort Sea	More Sensitive

[1]Colors represent the sensitivity general rankings, in which red indicates the most sensitive, orange is the 2nd most sensitive, yellow is the 3rd most sensitive, and green is the least sensitive.

The Southeastern U.S. and Gulf of Mexico broad OCS regions and planning areas had highest sensitivity ranks in both methods (Table 22). The moderate relative sensitivity scores of the Northeast U.S. are comparable to the average of the “less” and “most” sensitive categories of the North and Mid-Atlantic BOEM ratings. The low moderate relative sensitivity scores for California Current and Gulf of Alaska parallel those “less sensitive” scores from BOEM (BOEMRE 2010). East Bering Sea was ranked “least sensitive” by BOEM in 2010, but scored in the low-moderate range in this study. Most surprising were results for the Chukchi/Beaufort Sea, which ranked lowest for oil and gas in this study, but were ranked from less to more sensitive depending on the individual planning area in the previous BOEM evaluation (BOEMRE 2010).

The new RESA method expands the previous analysis in terms of the number and types of ecological components and the types of impacts. The previous assessment focused on sensitivity to defined impacts (physical disturbance, sound, oil spills, and accidental spills). The new RESA method expands the list of impacts, includes an additional BOEM activity (renewable energy), and incorporates resilience into the assessment.

The original sensitivity method relied on four components: coastal habitats, marine habitats, marine fauna, and marine productivity. The new RESA method expands and improves the first three components. Both methods utilize NOAA’s ESI. The ESI results for the RESA (Section 3.2.2 and Appendix E), which update previous scores with the most recent (2012) data in electronic format, compare favorably with those presented in BOEMRE (2010).

The new RESA model also expands the types of habitats from the BOEM analysis (BOEMRE 2010) to include estuarine benthic and pelagic habitats. While some of the same habitats are considered in both models (e.g., vegetated, tropical, and deep sea corals), the RESA model explores the sensitivity in a more rigorous way – examining the vulnerability, intolerance, and recovery of individual habitats, along with a relative abundance factor, rather than simply a ranked abundance and sensitivity value. BOEM’s 2010 method includes the number of MPAs and critical habitats in each planning area. This RESA considers MPAs as impact-independent factors; critical habitats are assessed as part of the individual conservation species. These factors could account for the ranking differences in habitat scores between the two methods. The new RESA method ranked the Eastern and Western Gulf of Mexico and Southeast U.S. regions highest in terms of habitat sensitivity to oil and gas activities, whereas the original sensitivity analysis (BOEMRE 2010) ranked the Eastern Gulf of Mexico, Central California, and Washington/Oregon regions the highest for those activities.

The biggest change in the new RESA method is the reliance on individual species rather than species groups. In addition, the species components have been expanded to include invertebrates. Depending on the species group, BOEM’s 2010 method uses a combination of relative abundance or stock assessment, number of ESA-listed species, and, in the case of marine mammals and sea turtles, susceptibility to impacts from oil spills and anthropogenic sound.

Inherent in this method was the concept that the number of ESA-listed species is directly related to relative sensitivity. RESA uses a more refined approach to measure sensitivity that relies on representative listed species, their potential exposure to impacts, and their ability to recover. Given this difference in approach, it is not surprising that sensitivity based on individual species and their individual response is quite different than sensitivity based on proxies such as number of listed species, or total landings or abundance of a species group. The new RESA method scored the Gulf of Mexico regions highest in terms of species sensitivity to oil and gas, whereas the original BOEM method gave these areas only moderate scores. Pacific OCS Planning areas were scored high by the original BOEM method, but only scored moderate by the new RESA method. Both methods scored the Chukchi/Beaufort Sea region lowest in terms of species sensitivity.

The new RESA method produced results that are an improvement over the original BOEM methods (MMS 2007a, BOEMRE 2010) because they have been expanded to include additional BOEM activities. In addition, these results are scalable, so that additional elements, such as additional BOEM activities, more detailed geography, and additional species/habitats can be easily added. Most importantly, the scoring process can be independently validated and is supported by scientific literature wherever possible.

3.2. EXPLORATION OF CONTROLLING FACTORS

It is informative to understand how the scoring of individual species and habitat parameters individually contribute to the sensitivity scores in each of the broad OCS regions. Only in this way is it possible to fully appreciate the robustness of the RESA method and to understand how it can be improved in future versions.

3.2.1 Species

The RESA method allowed for a selection of 17 species (five mammals or turtles, four birds, four fish, and four invertebrates) to represent each of the nine broad OCS regions. All 17 species were selected in all but two regions (Table 3). Since there are no federally listed fish in the Chukchi/Beaufort Sea and East Bering Sea broad OCS regions, there was no fish species of conservation importance to include in the scoring. Consistent selection of conservation species across all broad OCS regions appropriately weights the conservation element for these two regions. As a result, only three fish species were scored from these two regions, with a total of 16 species contributing to the total score.

Sensitivity scores for species and habitats were examined individually to understand how each contributed to the overall sensitivity scores. First, sensitivity scores for each species were summed for each broad OCS region and BOEM activity. Raw scores for each species are shown in Table F-1, Appendix F, with the 10 highest scores shown in Table 23.

Table 23: Species with 10 Highest Average Sensitivity Scores for each Broad OCS Region (combined for both BOEM activities)

Selected Species	Atlantic		Gulf of Mexico		Pacific		Alaska			Ave. Score
	NECS	SECS	EGOM	WGOM	CALC	WAOR	CBS	EBS	GOAK	
Florida manatee	---[1]	46	46	---	---	---	---	---	---	**46.0**
Atlantic sturgeon	32	32	---	---	---	---	---	---	---	**32.0**
Atlantic spotted dolphin	---	31	---	---	---	---	---	---	---	**31.0**
Loggerhead turtle	---	27	---	---	---	---	---	---	---	**27.0**
Baltic macoma clam	---	---	---	---	---	---	25	25	26	**25.3**
Polar bear	---	---	---	---	---	---	25	---	---	**25.0**
Red snapper	---	---	---	23	---	---	---	---	---	**23.0**
Glaucous-winged gull	---	---	---	---	---	15	---	26	27	**22.7**
Double-crested cormorant	22	22	22	23	---	---	---	---	---	**22.3**
Smalltooth sawfish	---	---	22	---	---	---	---	---	---	**22.0**
Spectacled eider	---	---	---	---	---	---	22	---	---	**22.0**

[1] A blank score indicates that the species was not selected for analysis in that Broad OCS Region based on criteria in Section 2.1.5.
See Table F-1 for all species scores.

The species in Table 23 had the highest contribution to the total sensitivity score for the broad OCS regions in which they were scored. With the exception of the California Current, each broad OCS region contained at least one of the highest-scoring species.

Florida manatee, a marine mammal, had the highest sensitivity score, and was scored for both the South Atlantic and Eastern Gulf of Mexico broad OCS regions. Florida manatees live in shallow water and are slow-moving air breathers with low reproductive rates (USFWS 2001). As a result, they had high scores for vulnerability and low to moderate scores for resilience to impacts from oil and gas activities including accidental spills, vessel strikes, and oil spills (Table 24). Sensitivity scores for Florida manatee were lower for renewable energy activities than for oil and gas and these scores reflected a moderate vulnerability and low to moderate resilience to vessel strikes, habitat disturbance, and sound and noise. The manatee's specific feeding habits rely on submerged aquatic vegetation, which resulted in high vulnerability and low resilience to habitat disturbance from renewable energy.

A small difference among similar planning areas for the same species may be indicative of the level of activity. For example, the slightly higher sensitivity score for the Baltic clam in the Gulf of Alaska Broad OCS region in comparison to Chukchi/Beaufort Sea and Eastern Bering Sea Broad OCS regions (Table 23) results from the consideration of the higher level of oil and gas activity in the Gulf of Alaska Broad OCS region.

Table 24: Vulnerability, Resilience, and Sensitivity Scores for Florida Manatee for Southeastern U.S. Broad OCS region

	Oil and Gas			Renewable Energy		
Impact Factor	**Vulnerability**	**Resilience**	**Sensitivity**	**Vulnerability**	**Resilience**	**Sensitivity**
Accidental Spill	1.0	3.2	6.9	1.00	7.2	2.9
Artificial Light	0.1	8.7	0.1	0.26	8.7	0.3
Collision w/ Above-Surface Structure	0.0	9.0	0.0	0.00	9.0	0.0
Habitat Disturbance	0.1	1.0	0.9	0.60	2.6	4.4
Sound/Noise	0.3	2.8	2.3	0.77	2.4	5.8
Vessel Strikes	0.8	0.8	7.1	0.67	0.8	6.1
Oil Spill (Oil and Gas Only)	1.0	0.7	9.3	---	---	---
Total	**3.3**	**26.2**	**26.5**	**3.3**	**30.7**	**19.6**

Atlantic sturgeon, a federally-listed endangered fish selected for North and South Atlantic broad OCS regions, had the next highest sensitivity score. The distribution of Atlantic sturgeon in shallow coastal waters, combined with their slow reproductive rate and sensitivity to barotrauma, resulted in high sensitivity scores for oil spills, vessel strikes, and sound from oil and gas activities; and habitat disturbance, vessel strikes, and sound from renewable energy (Table 25).

Table 25: Vulnerability, Resilience, and Sensitivity Scores for Atlantic Sturgeon for Southeastern U.S. Broad OCS region

	Oil and Gas			Renewable Energy		
Impact Factor	**Vulnerability**	**Resilience**	**Sensitivity**	**Vulnerability**	**Resilience**	**Sensitivity**
Accidental Spill	1.0	8.0	2.0	1.0	8.0	2.0
Artificial Light	0.1	8.7	0.1	0.2	8.7	0.2
Collision w/ Above-Surface Structure	0.0	9.0	0.0	0.0	9.0	0.0
Habitat Disturbance	0.1	2.6	0.7	0.7	2.6	4.9

	Oil and Gas			Renewable Energy		
Impact Factor	**Vulnerability**	**Resilience**	**Sensitivity**	**Vulnerability**	**Resilience**	**Sensitivity**
Sound/Noise	0.3	3.0	2.2	0.8	2.4	6.1
Vessel Strikes	0.4	1.7	3.1	0.4	1.7	3.0
Oil Spill (Oil and Gas Only)	1.0	2.3	7.7	---	---	---
Total	**2.8**	**35.3**	**15.8**	**2.9**	**32.4**	**16.2**

The contribution of each ecological component for each broad OCS region and BOEM activity is shown in Table 26 and Figures 4 and 5. By design, each ecological component makes relatively equal contributions to the model (four species of birds, invertebrates, and fish per broad OCS region, five species for marine mammals and sea turtles, combined as air-breathing animals). On average, marine mammals and sea turtles had the highest sensitivity scores for oil and gas activities, followed by invertebrates. Birds and invertebrates were the largest contributors to the renewable energy sensitivity scores. However, individual broad OCS regions differed in terms of the relative contributions of the various ecological components. For oil and gas, marine mammals and sea turtles together had the highest scores in each broad OCS region (Table 26, Figure 4). Invertebrates and fish had lower sensitivity scores in their overall contribution in the Atlantic. Birds, fish, and invertebrates had similar scores in both Gulf of Mexico broad OCS regions. Birds and invertebrates had lower sensitivity scores in the Pacific broad OCS regions and invertebrates had the second-highest contribution in the Alaskan broad OCS regions.

Table 26: Species Sensitivity Scores by Ecological Component for Each Broad OCS Region and BOEM Activity

Broad OCS Region		Oil and Gas				Renewable Energy			
		Birds	**Fish**	**Invert-ebrates**	**Marine Mammals and Sea Turtles**	**Birds**	**Fish**	**Invert-ebrates**	**Marine Mammals and Sea Turtles**
Atlantic	NECS	18.8	44.1	45.3	98.5	10.2	25.6	15.7	10.2
	SECS	26	44.4	43.4	97.3	12.1	21.7	21.2	26.8
Gulf of Mexico	EGOM	46.6	41.5	42.5	92.7	14.4	13.9	23.9	21.2
	WGOM	41	47.4	44.9	85.6	14.2	21.3	24.1	1.4
Pacific	CALC	43.7	34.2	44.6	54.2	14.5	5	15.2	0.9
	WAOR	45.4	23.3	46.7	56.7	7.7	0.3	20.7	0.9
Alaska	CBS	27.7	12.6	53.9	58.6	25.3	3.3	13.3	4.7
	EBS	46.1	35.7	53.7	54.8	28.4	3.8	12.6	1.6
	GOAK	41.2	35.8	52.2	54.7	25	2.5	12.2	1.8
Mean		**37.4**	**35.4**	**47.5**	**82.1**	**16.9**	**10.8**	**17.7**	**7.9**

The relative contributions of ecological components were lower for renewable energy in comparison to oil and gas (Table 26, Figure 5). Fish made the largest contribution to sensitivity scores in the Northeastern U.S. broad OCS region, and marine mammals/sea turtles made the largest contribution in the Southeastern U.S. broad OCS region. Invertebrates and mammals/turtles scored highest in the Eastern Gulf of Mexico broad OCS region, but invertebrates and fish scored highest in the Western Gulf of Mexico broad OCS region. In the Pacific broad OCS region, invertebrates scored highest, with birds a close second in the California Current broad OCS region. Birds made the highest contribution to renewable energy species sensitivity in all Alaskan broad OCS regions.

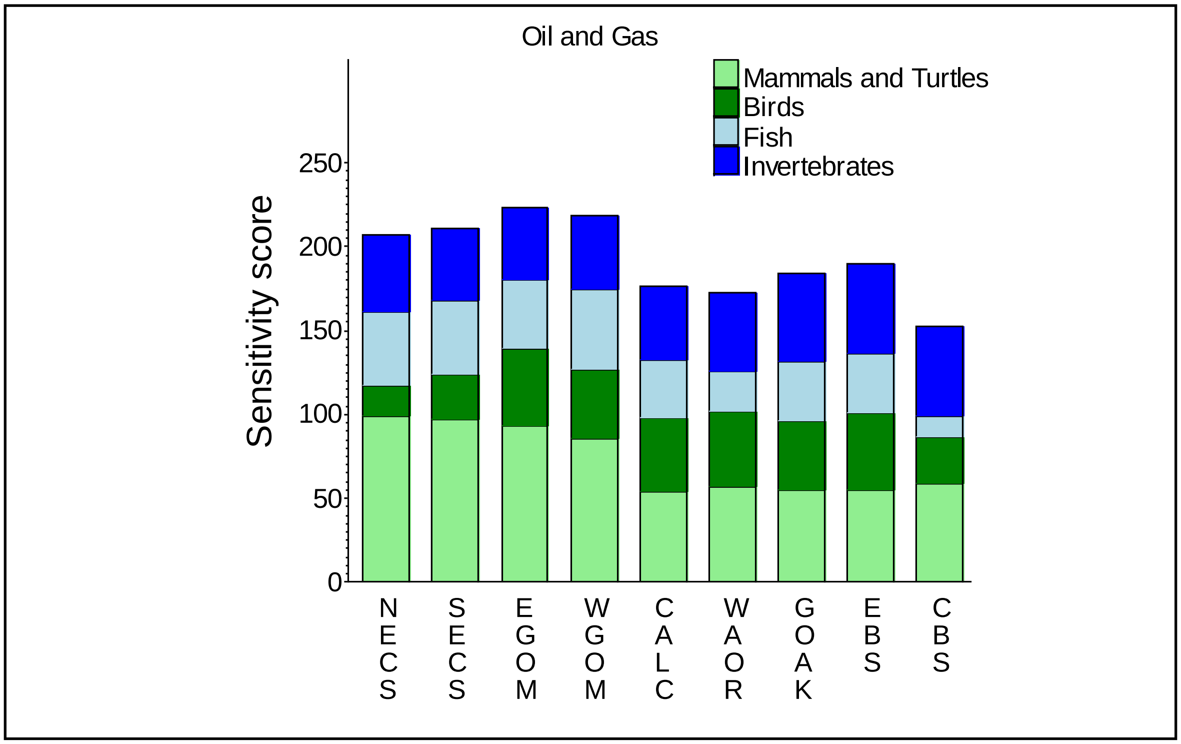

Figure 4: Species sensitivity scores for each broad OCS region for oil and gas activities

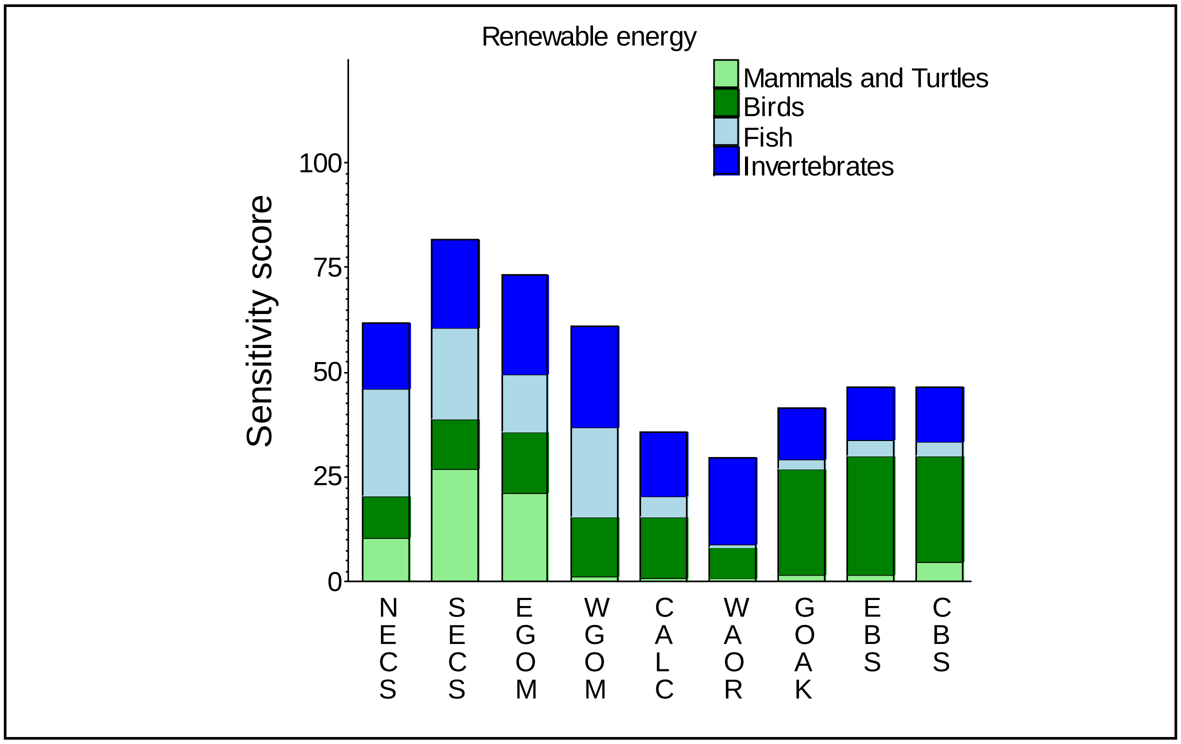

Figure 5: Species sensitivity scores for each broad OCS region for renewable energy activities

Species were selected based on three different ecological components: conservation importance, fisheries importance, and ecological role; however, these components are not represented equally. Seven species of conservation importance were included in the RESA model, six of ecological importance and four of fisheries importance for each respective broad OCS region. Species of conservation importance contributed the most to the overall score for oil and gas activities as well as for each broad OCS region except East Bering Sea (Table 27). Ecological role species made the next highest contribution, followed by fisheries importance, paralleling the number of taxa in each category. For renewable energy activities, ecological role species contributed most to the overall sensitivity score for this activity. However, the contributions of the species types were not consistent across the broad OCS regions. Species of conservation importance contributed most to overall sensitivity in the Atlantic and Eastern Gulf of Mexico regions; species of fisheries importance contributed the most in the Washington/Oregon broad OCS region, and ecological role species contributed the most for the remaining broad OCS regions.

Scores for oil and gas were at least double, and as much as five times higher, than those for renewable energy (Table 27). The Southeast Atlantic broad OCS region had the highest scores for renewable energy. This was largely driven by the three species of conservation importance with highest scores (Florida manatee, Atlantic sturgeon, and loggerhead sea turtle; see Table 23).

Table 27: Species Sensitivity Scores by Parameter Selection Categories for each Broad OCS Region and BOEM Activity

Broad OCS Region		Oil and Gas				Renewable Energy			
		CI	ER	FI	Total	CI	ER	FI	Total
Atlantic	NECS	99.6	71.6	35.5	206.7	27.7	17.3	16.7	61.7
	SECS	97.7	72.7	40.6	211.0	40.2	23.2	18.5	81.9
Gulf of Mexico	EGOM	120.1	59.5	43.6	223.2	35.4	26.3	11.6	73.3
	WGOM	101.1	70.5	47.4	219.0	9.5	31.7	19.8	61.0
Pacific	CALC	88.2	62.3	26.2	176.7	10.4	17.6	7.5	35.5
	WAOR	89.1	56.3	26.8	172.2	7.3	9.4	13.0	29.7
Alaska	CBS	68.2	53.4	31.2	152.8	18.7	22.8	5.1	46.6
	EBS	66.5	72.0	51.8	190.3	9.6	33.3	3.5	46.4
	GOAK	70.9	66.3	46.6	183.8	7.4	31.2	2.9	41.5
Total		**801.4**	**584.6**	**349.7**	**1735.7**	**166.2**	**212.8**	**98.6**	**477.6**

CI = Conservation Importance, ER = Ecological Role, FI = Fisheries Importance

The sum of all species scores for each BOEM activity and broad OCS region is shown in Table 28. For the two activities combined, the Eastern Gulf of Mexico broad OCS region scored highest, followed by the Southeastern U.S. broad OCS region. Next highest was the Western Gulf of Mexico broad OCS region, followed by the Northeastern U.S. broad OCS region. The Washington/Oregon and Chukchi/Beaufort Sea broad OCS regions were lowest-scoring for the two activities combined. Oil and gas activities contributed more than 75 percent of the total species sensitivity for all broad OCS regions. For this activity, the Gulf of Mexico broad OCS regions had the highest scores, with the Eastern Gulf slightly higher than the Western Gulf. The Atlantic broad OCS regions were next highest, with the Southeastern Atlantic broad OCS region slightly higher than the Northeastern Atlantic broad OCS region. The Chukchi/Beaufort Sea broad OCS region had the lowest score for oil and gas. For renewable energy, the Southeastern U.S. broad OCS region had the highest species score, followed by the Eastern Gulf of Mexico, Northeastern U.S., and Western Gulf of Mexico broad OCS regions. The Washington/Oregon broad OCS region had the lowest score.

Table 28: Total Sensitivity Scores for Species by BOEM Activity and Broad OCS Region

Broad OCS Region		Oil and Gas	Renewable Energy	TOTAL
Atlantic	NECS	206.7	61.7	268.4
	SECS	211.1	81.8	292.9
Gulf of Mexico	EGOM	223.2	73.3	296.5
	WGOM	219.0	61.0	279.9
Pacific	CALC	176.7	35.6	212.3
	WAOR	172.1	29.6	201.7
Alaska	CBS	152.8	46.6	199.4
	EBS	190.3	46.4	236.6
	GOAK	183.8	41.4	225.3
TOTAL		**1735.7**	**477.4**	**1987.7**

3.2.2 Habitats

Individual habitats were the other important element of the relative sensitivity scoring. The ten highest individual habitat scores for each broad OCS region, totaled for the two types of BOEM activities, are listed in Table 29, with a complete list provided in Table F-2, Appendix F. Table 29 lists the habitats in order of average score, allowing an understanding of the habitats that contribute most to the overall sensitivity score. Sabellariid Worm Reef substrate, a marine benthic habitat created from the tubes of sabellariid worms (also known as feather dusters), scored highest of all habitats. In the broad OCS regions, this nearshore substrate occurs only in the Atlantic off the coast of Florida (Zale and Memfield 1989), and therefore was scored only for the Southeastern U.S. Atlantic broad OCS region. The high sensitivity score is based on high vulnerability to oil spills, and high vulnerability to accidental spills and habitat disturbance from renewable energy activities, with low to moderate resilience (Table 30).

Table 29: Ten Highest- Scoring Habitats with Scores for Each Broad OCS Region Totaled for BOEM Activities

Selected Habitats		Atlantic		Gulf of Mexico		Pacific		Alaska			Mean
		NECS	SECS	E	W	CALC	WAOR	CBS	EBS	GOAK	
M/B	Sabellariid Worm Reef	---	19	---	---	---	---	---	---	---	**19.0**
M/B	Live Hard Bottoms	---	---	16	---	---	---	---	---	---	**16.0**
M/B	Nearshore FUS	---	---	---	---	13	13	13	14	16	**13.8**
E/P	Open Water	12	16	14	12	11	15	---	---	---	**13.3**
M/B	Submerged Aquatic Vegetation	---	---	13	---	---	---	---	---	---	**13.0**
M/P	Algal Rafts (*Sargassum*)	---	15	10	---	---	---	---	---	---	**12.5**
E/B	Aquatic Vascular Vegetation	18	18	---	15	7	7	---	9	9	**11.9**
E/B	Mollusk Reef	---	---	10	---	---	---	---	---	---	**10.0**
M/B	Shallow/ Mesophotic Coral	---	10	---	---	---	---	---	---	---	**10.0**
M/P	Surface/ Photic Zone	9	---	---	10	---	---	---	---	---	**9.5**

M = marine; E = estuarine; B =benthic; P = pelagic; FUS = fine unconsolidated substrate. A dash indicates that habitat was not selected for analysis for that Broad OCS planning area based on criteria in Section 2.1.6.See Table F-2 for complete habitat scores.

Estuarine Aquatic Vascular Vegetation habitat on the Atlantic coast had the second-highest scores. This habitat is composed of eelgrass (*Zostera marina*) communities in the Northeastern U.S. broad OCS region and eelgrass and seagrass (*Thalassia testudinum*) communities in the Southeastern U.S. broad OCS region. High vulnerability and low resilience to oil spills, vessel strikes (for oil and gas and renewable energy), and accidental spills (for renewable energy only, as these energy sources tend to be closer to shore and overlap with the habitat's distribution) resulted in high scores for these two broad OCS regions. Estuarine aquatic vascular vegetation in the Eastern Gulf of Mexico broad OCS region, composed of seagrass (*T. testudinum*), had a slightly lower sensitivity score, a result of a slightly lower intolerance to these impacts.

Table 30: Impact Factors versus Vulnerability, Resilience, Pre-abundance Sensitivity, Abundance Rank, and Sensitivity Scores for Sabellariid Worm Reef for Southeastern U.S. Broad OCS Region

	Oil and Gas					Renewable				
Impact Factor	**Vul.**	**Res.**	**Pre-Abundance Sens.**	**Abundance Rank**	**Sens.**	**Vul.**	**Res.**	**Initial Sens.**	**Abundance Rank**	**Sens.**
Accidental Spill	0.43	3.2	3.0	0.60	1.8	1.00	3.2	6.9	0.60	4.1
Artificial Light	0.00	3.9	0.0	0.60	0.0	0.00	3.9	0.0	0.60	0.0
Collision w/ Above Surface Structure	0.00	5.8	0.0	0.60	0.0	0.20	5.8	0.0	0.60	0.0
Habitat Disturbance	0.19	1.8	1.5	0.60	0.9	0.79	2.6	5.8	0.60	3.5
Sound/Noise	0.43	6.0	0.0	0.60	0.0	0.89	5.6	0.0	0.60	0.0
Vessel Strikes	0.39	2.4	2.9	0.60	1.8	0.39	2.4	2.9	0.60	1.8
Oil Spill (Oil and Gas Only)	1.00	1.5	8.5	0.60	5.1	---	---	---	---	---
TOTAL	**2.43**	**24.58**	**15.86**	**4.20**	**9.52**	**3.26**	**23.48**	**15.58**	**3.60**	**9.35**

Vul. = Vulnerability
Res. = Resilience
Pre-Abundance Sens.- Sensitivity score prior to adjustment for relative abundance or coverage in the broad OCS region
Sens. = Sensitivity

Live Hard Bottom habitats scored relatively high (Table 29), contributing to the score for the Eastern Gulf of Mexico broad OCS region (Table 31). This habitat, unique to the northeastern Gulf of Mexico (Thompson et al. 1999), consists of low-relief rock substrate that supports dense colonies of epifauna, which attract fish and sea turtles. The high sensitivity score is based on high vulnerability to oil spills and habitat disturbance from oil and gas activities, with a moderate recovery rate. Four other habitats scored relatively high. Fine Unconsolidated Substrate (FUS), a marine benthic habitat found in the nearshore areas of the Pacific and Alaskan broad OCS regions, had relatively high habitat sensitivity scores (Table 29). The high sensitivity scores resulted from high vulnerability and moderate recovery rates from oil spills, and to a lesser extent, habitat disturbance. Similarly, FUS also scored high in the Western Gulf of Mexico for the same reasons (Table F-2, Appendix F). This habitat has a wider areal range in this region, and is often found in deeper waters than in the Pacific and Alaskan regions. Open Water in the Estuarine Pelagic Zone, analyzed for Atlantic and Pacific planning areas, scored relatively high, especially in the South Atlantic, Eastern Gulf of Mexico, and Washington-Oregon broad OCS regions. The scoring reflects the high vulnerability to and moderate recovery from oil spills.

Table 31: Scores for Sensitivity of Benthic and Pelagic Habitats in Estuarine and Marine Environments to Oil and Gas and Renewable Energy Activities, by Ecoregion

Ecoregion		Oil and Gas					Renewable Energy				
		ESI	Estuarine		Marine		ESI[1]	Estuarine		Marine	
			Benthic	Pelagic	Benthic	Pelagic		Benthic	Pelagic	Benthic	Pelagic
Atlantic	NECS	8.7	9.6	5.9	12.1	7.8	0.0	8.1	5.8	0.1	1.1
	SECS	9.2	9.5	9.1	19.7	9.2	0.0	8.5	7.3	14.9	5.6
Gulf of Mexico	EGOM	9.2	5.7	7.5	25.7	7.3	0.0	4.5	6.8	8.9	2.2
	WGOM	8.4	8.4	7.1	22.9	9.0	0.0	6.8	4.6	5.5	1.2
Pacific	CALC	6.5	4.6	7.0	22.9	3.0	0.0	2.6	4.4	2.1	2.9
	WAOR	7.0	4.8	8.4	15.0	3.1	0.0	2.0	6.9	1.5	3.0
Alaska	CBS	7.3	3.4	5.5	16.9	1.8	0.0	3.5	1.2	6.2	0.0
	EBS	6.1	4.8	5.9	19.5	6.8	0.0	4.1	3.7	3.3	0.5
	GOAK	5.8	4.9	6.0	17.7	3.2	0.0	4.2	3.8	5.7	3.1
Total		**68.2**	**55.7**	**62.4**	**172.4**	**51.2**	**0.0**	**44.3**	**44.5**	**48.2**	**19.6**

[1] This assumes no shoreline habitat impacts from renewable energy development projects

Sargassum algal rafts, scored for Southeastern Atlantic and Eastern Gulf of Mexico broad OCS regions, scored high in the Southeastern Atlantic broad OCS region (Table 29). The score reflects high sensitivity to oil spills and accidental spills from renewable energy activities.

Many of the lowest scoring habitats were located in or ranged into deep waters, and thus were not highly vulnerable to BOEM activities. These included Seamounts, Ridge/Rock, Deep/Coldwater Coral, and Boulder/Rock (Table F-2, Appendix F).

Individual sensitivity scores were totaled for each habitat component. ESI scores were incorporated into the scoring process to represent the sensitivity of shoreline habitats to oil and gas activities. Since activities resulting from renewable energy exploration and generation generally do not occur in coastal habitats, an ESI value of zero was deemed appropriate for all renewable energy impact factors (Tables 31 and 32).

Table 32: Total Habitat Sensitivity Scores to Oil and Gas and Renewable Energy Activities, by Ecoregion

Ecoregion		Oil and Gas			Renewable Energy			Total
		ESI	Habitat[1]	Total[2]	ESI[3]	Habitat[1]	Total[2]	
Atlantic	NECS	8.7	35.5	44.2	0.0	15.0	15.0	59.2
	SECS	9.2	47.5	56.7	0.0	36.3	36.3	93.0
Gulf of Mexico	EGOM	9.2	46.2	55.4	0.0	22.4	22.4	77.8
	WGOM	8.4	47.4	55.8	0.0	18.1	18.1	73.9
Pacific	CALC	6.5	37.4	43.9	0.0	12.1	12.1	56.1
	WAOR	7.0	31.2	38.2	0.0	13.5	13.5	51.7
Alaska	CBS	7.3	27.5	34.8	0.0	10.9	10.9	45.7
	EBS	6.1	37.0	43.1	0.0	11.5	11.5	54.6
	GOAK	5.8	31.9	37.7	0.0	16.8	16.8	54.4
Total		**68.2**	**341.6**	**409.8**	**0.0**	**156.6**	**156.6**	**566.4**

[1] Combined sensitivity of benthic and pelagic habitats in estuarine and marine environments (as listed in Table 31) to this BOEM activity,
[2] Sum of ESI and combined habitat sensitivity for this BOEM activity
[3] This assumes no shoreline habitat impacts from renewable energy development projects

The distribution of habitat scores among the habitat types is shown in Table 31 and Figures 6 and 7. Overall, Marine Benthic habitats made the highest contribution to the total habitat sensitivity score for oil and gas, with the remaining habitat components having similar levels of contribution. This largely reflects the number of habitats scored (4) in comparison to one habitat scored for each other component. For renewable energy, Estuarine Benthic and Pelagic (one habitat each) and Marine Benthic (four habitats) made roughly equivalent contributions to the overall score, with the Marine Pelagic habitat contributing less than half of the other habitats. When habitat scores are compared between BOEM activities, total oil and gas sensitivity scores were higher than for renewable energy. These differences were largest for the Marine/Benthic habitats and smaller for the other habitat types (Table 31).

Total ESI and habitat scores for each broad OCS region are shown in Table 32. Habitat sensitivity scores for oil and gas activities were much higher, generally two to three times higher, than those for renewable energy, with one exception (Table 32). The Southeast Atlantic score for renewable energy was roughly comparable to the score for oil and gas, due largely to the high sensitivity of Sabellariid Worm Reef substrate and Estuarine Aquatic Vascular Vegetation.

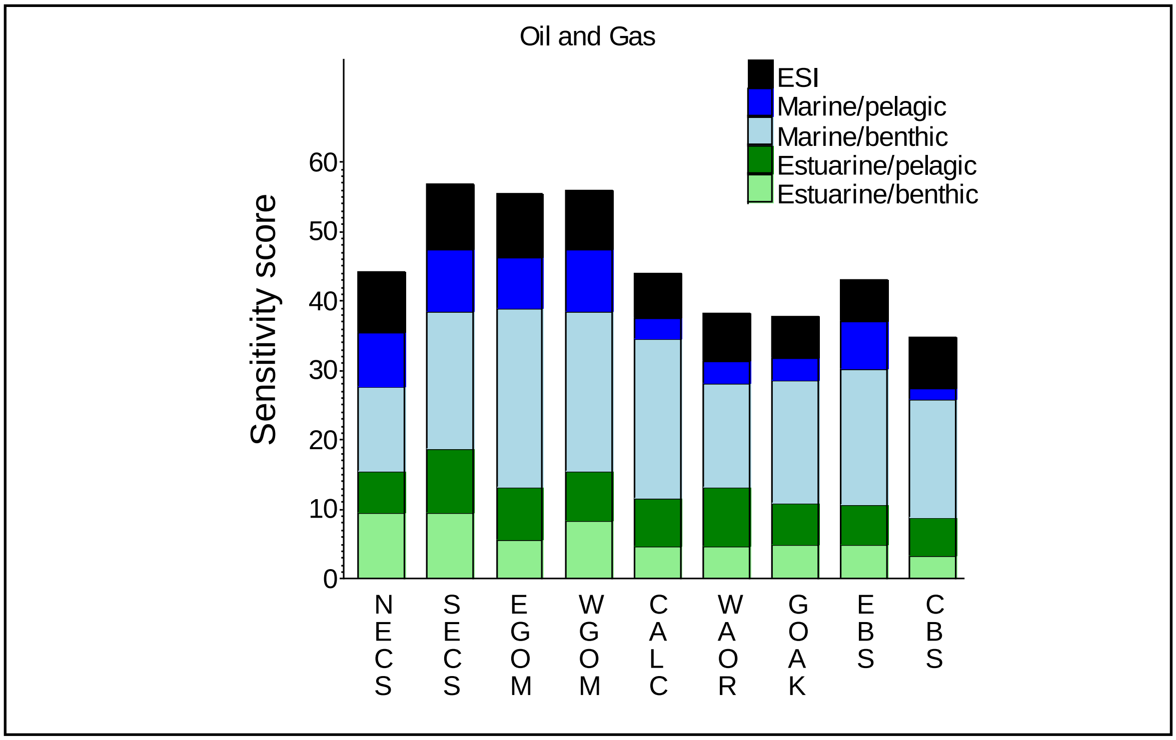

Figure 6: Habitat sensitivity scores for each broad OCS region for oil and gas activities

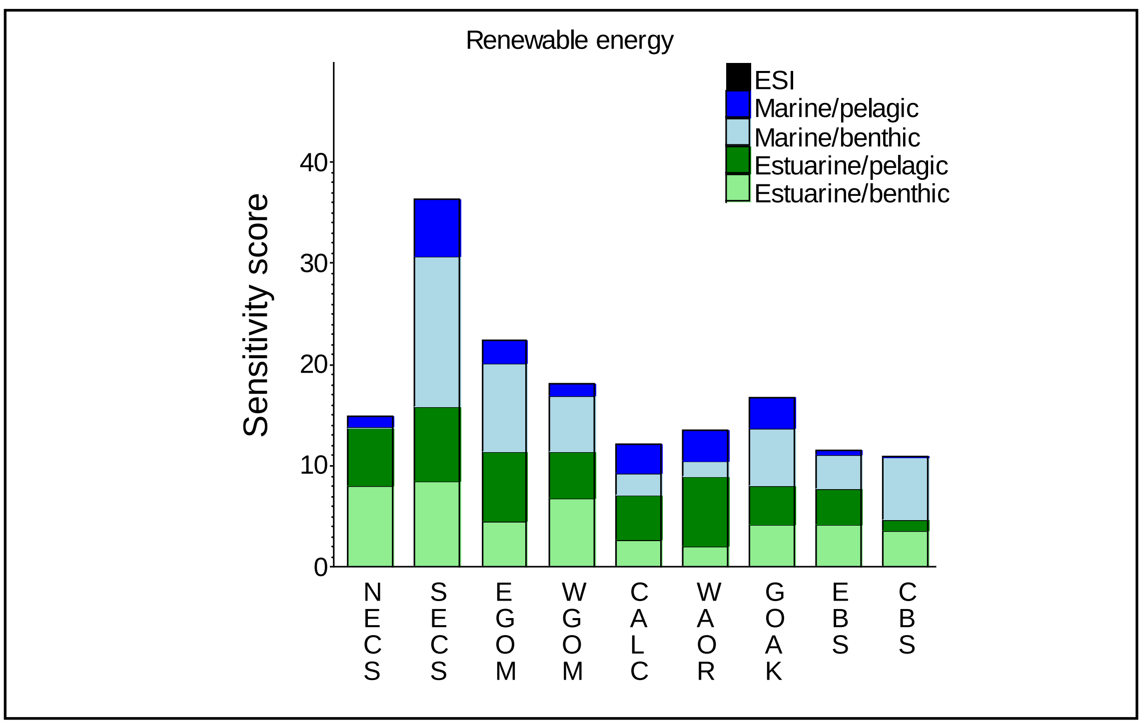

Figure 7: Habitat sensitivity scores for each broad OCS region for renewable energy activities

For oil and gas activities, the Gulf of Mexico and Southeast Atlantic broad OCS regions scored highest in terms of habitat sensitivity. California Current and East Bering Sea broad OCS regions had moderately high scores, followed by the Northeastern U.S. broad OCS region. The Chukchi/Beaufort Sea broad OCS region scored the lowest. ESI values, which ranged from 5.8 (Gulf of Alaska broad OCS region) to 9.2 (Southeastern U.S. and Eastern Gulf of Mexico broad OCS regions) contributed less than 20% to the overall sensitivity score for oil and gas. For renewable energy activities, the Southeastern U.S. broad OCS region scored highest. The two Gulf of Mexico broad OCS regions scored moderately high, along with the California Current broad OCS region. The Washington/Oregon, Gulf of Alaska, and Chukchi/Beaufort Sea broad OCS regions scored lowest (Table 32).

3.3. IMPACT-INDEPENDENT MODIFICATION

In the ideal model, the final sensitivity value would be adjusted to account for impact-independent aspects of the marine environment. These would include a measure of the environmental stressors from sources not regulated by BOEM, adjustments that would account for ongoing climate change and differences in the perceived environmental sensitivity of the various OCS areas related to the relative number and size of MPAs they contain. These independent aspects of the OCS area are deemed to be outside the considerations of the present version of the BOEM RESA method. Consideration of these outside impacts may be added to a future version of the RESA method as an adjustment term that would modify the final scores, perhaps as a scaling multiplier that would be set, planning area by planning area, as an external input.

This demonstration example of the model included only the impact-dependent sensitivity. However, the potential role of the independent factors related to MPAs and climate change on the broad OCS regions are considered as descriptive additions to the demonstration example of the RESA method and are discussed below.

3.3.1 Climate Change

Climate change affects the physical conditions in the nearshore coastal and open ocean regions that may, in turn, affect the relative environmental sensitivity of the OCS Planning Areas to varying degrees. It is challenging to quantify and incorporate the effects into an environmental sensitivity model due to the complexities of the changes both on a temporal and spatial scale. However, the potential effects are described in a qualitative manner for consideration in future development of the model, perhaps as regional modification factors to the individual planning region scores.

Climate change impacts the ocean's physical properties such as temperature, winds, precipitation, currents, sea level, salinity, and upwelling. These physical changes in turn affect species and habitats. The potential effects of the changes in physical properties to environmental sensitivity are described below.

3.3.1.1 Temperature

For the next two decades, a warming of approximately 0.2°C per decade is projected for a range of Intergovernmental Panel on Climate Change (IPCC) emissions scenarios (IPCC 2007). Even if the concentrations of all greenhouse gasses and aerosols are kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected. Afterwards, temperature projections increasingly depend on specific emissions scenarios.

Atmospheric temperature rise has not been uniform. For example, the arctic temperatures have increased about twice as much as those in lower latitudes. Preferential warming in the Arctic is due in part to the ice-albedo effect, which occurs when highly reflective ice is replaced by less reflective water and land surfaces, resulting in increased heat absorption and reduced reflection back into the atmosphere.

Around 1970, ocean temperature measurements showed warming to at least 700 m, with stronger near-surface warming leading to increased thermal stratification of the water column (Levitus et al. 2009, Levitus et al. 2012). Ocean warming is penetrating deeper in the Atlantic Ocean Basin than in the Pacific Ocean due to the deep overturning circulation cell that occurs in the North Atlantic.

Increasing temperatures may affect:

1. Species composition – Distribution patterns and ranges of species may change. Southern species may shift northwards as water temperatures rise. Community-level shifts may occur and ecosystems functions may change. In addition, migratory patterns may change with shifts in suitable nursery areas, stopover habitat, and forage locations. The ability of species to adapt to different locations will depend, in part, on their ability to find and occupy suitable habitat. Climate-change driven impacts are overlain with other impacts on species and habitats such as overfishing and pollution.

2. Permafrost/sea ice thawing – The permafrost in the Alaskan Arctic has been thawing at a rate of up to 0.04 m/yr. The thawing of coastal soils may result in more rapid shoreline erosion. This effect would be exacerbated by reduced duration and extent of shoreline protection provided by landfast ice and more exposure to storms. The IPCC (2007) identified the Chukchi/Beaufort Sea as the most sensitive broad OCS region for permafrost thermal degradation effects.

Sea ice is especially affected by climate change because of sensitivity to warming (IPCC 2007). Sea ice provides forage, resting, and birthing platforms and along with the ice-water interface local upwelling for high productivity. Large quantities of algae growing beneath the ice surface are incorporated into the food chain as the ice melts. The most affected OCS planning areas would be the Beaufort, Chukchi, Hope Basin, Norton Basin, and St. Matthew-Hall.

3. Ocean dynamics – Ocean circulation may change with the warming of the atmosphere and ocean waters. Upwelling areas prevalent along the Pacific coast may be affected by changes in the dynamics of the Trade Winds. Some evidence suggests a reduction in upwelling along the Pacific coast of North America related to reduction in the strength of the Trade Winds (Barth et al. 2007). A reliable prediction of the effects of ocean dynamic changes on environmental sensitivity is not available.

3.3.1.2 Sea Level Rise

Global sea level rise has occurred as a result of thermal expansion of the oceans and accelerated melting of glaciers and ice sheets. Sea level rise predictions range from 8 to 24 inches by 2100 (IPCC 2007). In addition, there may be hotspots of accelerated sea level rise along the Atlantic coast of North America, for example, as a result of changes in ocean dynamics (Sallenger et al. 2012). The Gulf of Mexico coastline, especially along the Louisiana border, is also undergoing accelerated relative sea level rise due to local subsidence and lack of sediment replenishment. Because submergence hotspots occur as a result of local geologic conditions, it is possible to assign climate change-elevated environmental sensitivity to these areas.

3.3.1.3 Ocean Acidification

Atmospheric carbon dioxide (CO_2) reacts with seawater to form carbonic acid that leads to increased acidity in the oceans. Under a high emissions scenario, current ocean pH could be reduced by as much as 0.4 units by the year 2100 (NOAA 2012). Higher latitudes will experience the largest changes and impacts due to the increased solubility of CO_2 at lower temperature. Coral reef ecosystems are also expected to experience significant habitat loss due to climate change, because decreased seawater pH will make it difficult to maintain their calcium carbonate-based skeletons.

Ocean acidification affects the process of calcification by which organisms form shells and skeletons and has negative impacts on corals, mollusks, and some plankton species. These negative effects would, in turn, adversely impact species dependent on them as a food source. The negative effects would be relatively higher in cold water planning areas where seawater can absorb more CO_2. However, there are little observed effects of ocean acidification on ecological resources and, therefore, environmental sensitivity.

The cumulative effects of these varying physical factors will have different effects on each broad OCS region (Table 33). The Gulf of Alaska, Eastern Bering Sea, and Chukchi/Beaufort Sea broad OCS regions are expected to have the highest magnitude of climate change effects, with the Pacific Coast broad OCS region having the lowest. Future iterations of the model can apply an adjustment factor to the total sensitivity to account for anticipated climate change effects.

Table 33: Anticipated Effects of Climate Change on Environmental Sensitivity of the Broad OCS Regions

Broad OCS Region	Magnitude of Climate Change Effect	Factors
Northeast Atlantic	Moderate	Sea level rise; increased ocean temperatures; increased ocean acidification; change in ocean dynamics; species composition changes
Southeast Atlantic	Moderate	Increased ocean temperatures; species composition changes
Eastern Gulf of Mexico	Moderate	Increased ocean temperatures; species composition changes
Western Gulf of Mexico	Moderate	Increased ocean temperatures; species composition changes
California Current	Low	Increased ocean temperatures; upwelling effects; species composition changes
Washington Oregon	Low	Increased ocean temperatures; upwelling effects; species composition changes
Gulf of Alaska	Low	Increased ocean acidification; increased ocean temperatures; species composition changes
Eastern Bering Sea	High	Sea ice melt; permafrost thaw; increased ocean acidification; increased ocean temperatures; species composition changes
Chukchi/Beaufort Sea	High	Sea ice melt; permafrost thaw; increased ocean acidification; increased ocean temperatures; species composition changes

3.3.1.4 Other Large-Scale Environmental Changes

It is becoming increasingly clear that large-scale changes are occurring over periods of decades. The most dramatic and least controversial examples are the changes in the sea ice seasonal coverage along the shorelines of northern Alaska. Another example is climate change with implications for annual temperature patterns, changes in precipitation and freshwater inputs to the coastal area, changes in the frequency and intensity of storms, and other ramifications. Many of these changes are not well described due to inherent complexities. All these can be represented as factors in future versions of the RESA method.

3.3.2 Productivity

Productivity issues associated with RESA are addressed in the Balcom et al. (2011) report prepared for BOEM. BOEM considers that method and the RESA to be components that will work in conjunction to evaluate the relative sensitivity of planning areas. The Balcom et al. (2011) report revised an earlier primary productivity review (CSA 1990, 1991) and updated primary productivity estimates for each planning area. The Balcom et al. (2011) report also addressed secondary and tertiary productivity and potential impacts of OCS oil and gas activities on primary productivity, as well as climate change.

CHAPTER 4: DISCUSSION AND CONCLUSIONS

4.1. DISCUSSION

This report explains a new method for conducting an analysis of the relative environmental sensitivity of OCS areas regulated by BOEM. At the outset of this project, the direction of the work was quite broad. It was clear that a significantly improved method was needed, but it was unknown whether this was best achieved by incrementally improving the existing BOEM method (BOEMRE 2010), by adopting another method that had been developed elsewhere and described in the literature, by developing a hybrid of existing methods, or by creating a new purpose-built method of analysis. The goal was to attain a scientifically rigorous and largely objective approach that was well-suited to BOEM requirements. Its principal use is for periodic assessments of the relative suitability of OCS Planning Areas for regulated developments of oil and gas, renewable energy, and (for future iterations) mineral extraction.

The Study Team conducted an extensive review of the existing BOEM method (BOEMRE 2010) and others described in the literature. This review is discussed in detail in Appendix B. An assessment of these existing methods, along with a series of discussions with BOEM personnel, led to the conclusion that the effort to develop a new purpose-built approach was well-justified. To accomplish this, it was necessary to envision the effort in a manner similar to the classical sequence of design steps commonly applied in engineering design, especially where complex systems are involved. This sequence includes conceptual design, preliminary design, and final design. Committing to a final design in a single step can be inefficient or even self-defeating because alternatives may not have been appropriately considered, individual components may not be compatible, and the overall product may not function as intended. Instead, it is better to develop the design in stages, which also leads to the production of a prototype that can be tested and evaluated. Results of these tests are often used to further modify the design. Overall, the process offers many opportunities to systematically advance the suitability of the desired product by constructive feedback at each stage of development.

The development of the RESA method has generally followed these design steps and a prototype has been created and tested. The emphasis has been on producing a complete method with well-defined inputs and a structured hierarchy of analysis steps. The method is spreadsheet-based so that it can be readily implemented and it has been carefully constructed to allow its level of complexity to be scaled up or down. Where it was necessary to choose between expending effort on method development or in completing well-documented detailed input information, the former was favored to produce a well-designed but less detailed product. By advancing through the process this way, it is possible to better define the appropriate information and level of detail required at various steps in applying the method.

The new RESA method that has been developed satisfies the conceptual goals. It is robust and objective. Since the method is spreadsheet-based and electronic, it is transparent, easily validated, and ideally suited to the needs and requirements of BOEM. It can readily be scaled up or down in both the size of the geographic areas to be considered and in the number of parameters that are used.

The new RESA has been applied to the nine broad OCS regions that contain all 26 of the BOEM Planning Areas. As discussed earlier, these results are in general agreement with the relative environmental sensitivity levels determined by the earlier evaluation methods (MMS 2007a, BOEMRE 2010), which considered only oil and gas activities. Although the results of this analysis with the new RESA can be immediately utilized in assessing the OCS regions, the best output of this process has been in setting criteria for the selection of species and habitat parameters, learning how the complex interactions between the components control the results, determining the true level of detail required for the input data, and demonstrating that the whole system of evaluation works.

It is clear that development of the new RESA has been facilitated by concentrating on the broad goals of the project rather than the details that can be addressed in the subsequent development of this method. Therefore, a next generation of the RESA method could be developed by addressing issues that were bypassed to concentrate on method development in the current project. Two examples are the selection of the OCS areas to be covered (e.g., broad OCS regions, Planning Areas, or other more refined areas) and the determination of the optimum number of species and habitat parameters.

In the RESA model, a choice was made to apply the method to large regions determined by considering criteria for defining Large Marine Ecosystems and the established boundaries of the BOEM Planning Areas. These are the nine broad OCS regions. This was a pragmatic choice designed to avoid expending a large effort in determining an optimum unit of area to be used in the analysis and in establishing the boundaries of those areas. The rationale for the delineation of the BOEM Planning Areas is not well documented, but the boundaries were not entirely based on marine ecosystem considerations. Therefore, it is unlikely that the Planning Areas will represent a good choice for the optimum areas. Instead, it will be necessary to fully consider a range of ecological and environmental criteria, as well as the needs and limitations of the new RESA method in deciding how these areas are best defined.

Sensitivity scores resulting from the new RESA method are largely based on the species and habitat parameters that are used. Much was learned about the proper criteria for the selection of these parameters during the development of the method. Also, a certain amount of testing was done to establish the validity of these criteria and learn how deviations from these controls produced selections that affected the overall analysis. However, the optimum number and distribution of these parameters that should be used is yet to be determined. This can be resolved by additional attention to the definition of the selection criteria and by a rather arduous procedure involving trials with different numbers of these parameters. The number used in the new RESA method is certainly adequate, but it may also be increased in future versions. The results tabulation has shown that high-scoring species and habitats (e.g., manatees and Sabellariid Worm Reefs) drive the overall results of the RESA model presented herein. Future applications will likely include additional species and habitats, which would reduce the effects of a single, high-scoring species or habitat on sensitivity scores.

In the current application of the model, the species selection process produces a collection of species which may all contribute equally to the final RESA score. In other words, species selected to include in the model because of their high abundance (ecological role) carry just as much weight as species selected for their rarity (conservation importance). All species have a maximum potential sensitivity score of 10 prior to normalization, and this value does not differ based on species abundance or rarity. Under the limited number of species selected in this application of the model, only the most abundant and rarest species were selected. However, nuances exist in the relative abundance or rarity of each species. The previous BOEM methodology incorporated abundance information to emphasize the importance of abundant species groupings on the OCS. The RESA model presented herein may easily be altered to incorporate relative abundance/rarity characteristics of species. Application of a population weighting scheme may be used drive the "potential" score of a particular species up or down based on its abundance/rarity, therefore emphasizing the importance of certain species to a broad OCS region's relative environmental sensitivity.

The inputs to the Intolerance and Recovery attributes are categorical. The potential exists to increase the number of categories within each of these scoring factors, allowing for more accurate representation of each species within the model. The current breakdown of categories for each scoring factor is based on a balancing of data availability, user effort, and model accuracy. As any of these three factors change, the model framework may be changed accordingly (e.g., increased effort may be allocated, allowing for finer categorical breakdowns). For example, in terms of increasing the number of categories, answers to the reproductive rate question, which is an input to the Recovery attribute could be expanded. In the current setup of the model, the potential responses to this question are high and low. Given the scale of differences in reproductive rates of marine organisms, additional breakdowns of responses for this question would lead to a more accurate representation of the recovery ability of the species of interest.

An additional difficulty in the scoring arises from behavioral considerations. This is especially true of birds and mammals. Of all of the ecological components, bird species are the most difficult to score accurately with the model's vulnerability calculations. Birds have complex behaviors that are difficult to capture in the model. For example, birds spend time in flight, with differing proportions of time at differing heights, with particularly large differences between feeding and migration heights; birds also fly at differing times of day during migration, with varying maneuverability/avoidance behaviors. In addition, birds swim in water at varying depths and for various durations. Many species have aggregated behavior that is not fully considered in the model. For example, some bird species aggregate for feeding and spawning in very specific locations. This behavior is not unlike that of other species, such as groundfish and reef fish gathering at spawning areas. Some of these aggregations, especially for those species that are restricted to these specific habitats, would be especially sensitive to a localized, catastrophic event such as an oil spill. Since the model scores for an entire planning area, this extreme situation is not well represented. The lack of information about species-specific behaviors suggests that bird scores are less representative of sensitivity than scores for other species. It will be necessary to give consideration to additional RESA scoring procedures that would address this issue. BOEM's created a compendium of avian information for the Atlantic OCS (which was not available when this method was being tested) that can be used to improve the avian scoring process.

In the new RESA method, the impact data were determined from a variety of sources. As new information becomes available, impact information can be improved and refined in the next version of the model. The new RESA method includes energy-related impacts, both from renewable energy and energy-related mineral extraction (oil and gas). These activities occur across all OCS planning areas, and thus are appropriate for model development and testing. The model can be easily expanded to include non-energy mineral extraction activities such as sand and gravel mining. These activities should be added to future iterations of the model.

There are many other factors that can affect sensitivity. The new RESA model considers the level of existing BOEM activities in each broad OCS region. However, there are many other non-BOEM related factors that could affect sensitivity. In addition to the independent impact factors such as climate change, which is discussed in Section 3.3, these could include other factors such as commercial fishing, coastal eutrophication, nearshore development, and invasive species. An impact-independent factor that encompasses cumulative impacts could be developed for the next model iteration.

In the future, the RESA method can be continually improved with the addition of new data. The scoring relied mainly on species profiles and National Environmental Policy Act documents to assess species distributions, vulnerability to potential impacts, and recovery potential. As new information becomes available, the model can be easily updated. Areas where new data are needed include fish species of conservation importance in the Chukchi/Beaufort Sea or East Bering Sea broad OCS regions There are currently no federally-listed fish species in the Chukchi/Beaufort Sea or East Bering Sea broad OCS regions, but listings may occur in the future. New information is also needed on species' responses to impacts, especially those from renewable energy, an industry in its infancy in OCS waters, to refine model results. The Study Team intentionally decided not to use a marine spatial planning type of model because of the lack of geographically-based data across all OCS planning areas. However, geospatial data for species and especially habitats, once uniformly available for all planning areas, could be incorporated into the model to enhance sensitivity results.

The new RESA method is expected to continue to develop over time. This method, and subsequent versions, is designed as a key tool in the BOEM 5-year planning cycles. However, it can also be useful in a wide variety of other future applications. For example, its scoring can be adapted as a relative quantitative measure in assessments of the environmental cost versus benefit of potential future remediation actions.

Finally, relative environmental sensitivity of OCS areas continues to be evaluated separately from the possible response of marine productivity to BOEM-regulated activities. Future iterations of this method could consider adding productivity to the relative environmental sensitivity.

4.2. CONCLUSIONS

A largely quantitative and rigorous method for evaluating the relative environmental sensitivity of broad OCS regions to future BOEM-regulated activities has been created, tested, and applied to the areas covered by the 26 Planning Areas. The method is a substantial improvement over the method previously used by this agency and is clearly better suited to the needs of BOEM than any of the other similar methods that have been developed elsewhere. The present version of this method has produced traceable results in all areas to which it has been applied. It has served to provide assurance that the method is viable in the full range of applications needed to cover the broad regions of the OCS. It has provided different types of sensitivity results to demonstrate the influence of parameter selection criteria and to promote an understanding about how the components of the analysis interact to produce the final scores.

The new RESA method is an updated approach to the previous BOEM method that can readily be expanded and fine-tuned. It is also useful in establishing the need for an appropriate level of environmental data, much of which is available in a variety of literature sources, but some of which still needs to be developed.

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APPENDIX A: LITERATURE REVIEW AND INFORMATION SOURCES

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A.1 LITERATURE REVIEW

A.1.1 Scope of the Review

The literature review for the study included a review of methods used in sensitivity assessments and ecological value determinations and marine (and terrestrial) spatial planning. The original Environmental Sensitivity Index (NOAA 1997), BOEM's original Relative Environmental Sensitivity Assessment (MMS 2007), and the updated version (BOEMRE 2010) were carefully reviewed, assessing the methods strengths and areas for improvement. The original and revised productivity analyses (CSA 1990, 2011) were also examined for elements that could be incorporated into the study. The Study Team gathered relevant peer-reviewed literature through review of these documents, in house libraries from similar projects and literature searches. Studies that did not specifically pertain to approaches, methods, or concepts of marine environmental sensitivity regarding anthropogenic or natural stressors were generally excluded. Published, peer-reviewed, English language studies (or those that provided English language abstracts) that are indexed in scientific databases were the primary focus of the review, although relevant books, book chapters, government and industry technical reports, websites, and presentations were also selected for the data review.

A BOEM "white paper" (BOEMRE 2010) outlined considerations for developing the next method for environmental sensitivity analysis. The authors indicate that frequently-used terminology such as "sensitivity" and "resilience" are often subject to interpretation. The Study Team decided to define the most commonly used terms based on the literature, which establishes project- specific terminology and provides a common basis for method development. The definition for sensitivity, the foundation for this project, according to Zacharias and Gregr (2005), is "the degree to which marine features respond to stress," with stress defined as "the deviation of environmental conditions beyond the expected range." This definition was adapted to a project specific definition of "relative environmental sensitivity" as "the vulnerability and resilience of an OCS planning area's ecological components (i.e., habitats and biota) to the potential impacts of OCS oil and gas, marine minerals extraction and offshore alternative energy activities in the context of existing conditions (e.g., climate change forecast, regulatory status, and productivity)." This definition acknowledges Zacharias and Gregr (2005) tenet that sensitivity incorporates two important elements: vulnerability, "the probability that a feature will be exposed to a stressor to which it is sensitive," and response, which incorporates concepts variously defined as stability, fragility, or resilience. Resilience includes both capacity to absorb or resist change ("susceptibility") and the ability to recover or reverse (Levin and Lubchencko 2008). Resilience is highly dependent on scale, both temporal and spatial, (Levin and Lubchencko 2008), as well as the magnitude of the stressor (frequency and duration) and the level of response (Palumbi et al. 2008). The presence of other stressors ("cumulative impacts") also can affect resilience. There is some evidence that diversity improves resilience because of the redundancy in ecosystem roles (Palumbi et al. 2008). In addition, resilience, also defined as robustness (Levin and Lubchencko 2008), can be affected by species composition, specifically if there are keystone species or other critical species that play a pivotal role in the ecosystem. Redundancy can mediate the loss of a critical or keystone species. Productivity may also have a role in recovery rate, as higher productivity levels have been shown to speed recovery (Palumbi et al. 2008). The Study Team decided that all of these concepts needed to be represented in the chosen method and they have been a focus in the review of previous derived methods.

The Study Team reviewed a variety of approaches that analyzed ecosystems and their characteristics, including sensitivity, energy flow, value, status, vulnerability, and risk. Most of the literature was marine and estuarine-related, but some approaches were developed for terrestrial systems. The Study Team also reviewed literature on marine spatial planning to inform method development. Marine spatial planning uses a zoning approach to balance diverse ocean uses (Douvere 2008). The increase in marine data in geospatial form, for both natural resources and human use, has facilitated the growth of this mapping approach to ecosystem-based management. The definition of value in marine spatial planning ranges from an economically-derived definition of ecosystem goods and services to one that reflects intrinsic ecological value. The marine spatial planning process has been used to identify and designate MPAs. Specifically, the criteria that may be used in assessing ecological value (e.g., species rarity, critical habitat, fragility) overlap those that would be considered in an environmental sensitivity analysis. In addition, the various processes used to develop ecological value, which range from best professional judgment through a Delphic process to mathematical models, parallel the process used in this project. Some of the methods described in detail in Appendix B begin with a marine spatial planning or ecological value assessment, then add an adjustment to reflect sensitivity or vulnerability (Derous 2007a; Derous 2007b; Derous 2007c) or a risk assessment for human activities (Park et al. 2010; Park et al. 2011).

A.2 Database Methods

Project literature was stored and managed in a project database using the EndNote reference management software. Once references were selected by the Study Team (based on relevance to the project objectives), bibliographic data for the reference was either downloaded directly to the project database or saved (electronically downloaded in a tagged format or manually entered into a template) for later importation. Standard bibliographic data were collected for each reference (e.g., author, date, title, publisher, volume, pages, reference type). The Uniform Resource Locators (URLs) were also collected for websites or documents accessed online. Copyright status was reviewed for each reference, and where restrictions allowed, the abstract (if available) and full-text copy (in pdf format) of documents were included in the database.

Subject categories were used to organize the references using custom groups within the database. The keywords and geographic location further categorize the references for sorting and searching. Built-in sorting and search capabilities in EndNote software enable users to create customized reference categories for data output.

A.2.1 INFORMATION SOURCES

The Study Team investigated potential sources of data and information that could be used in the BOEM Relative Environmental Sensitivity and Productivity Analysis. Although the exact types of data needed for the analysis were still being developed, the team assumed that the analysis would use data for similar ecological components (coastal habitats, marine habitats, marine productivity and marine fauna) as were used in the previous BOEM methods (BOEMRE 2010). The data search focused on recent, readily-available sources, with data in electronic format, rather than in print. The team began with a review of data sources used in BOEM's 2010 relative ESA (BOEMRE 2010). A second important source of information was BOEM's various environmental studies and data synthesis projects that are captured in BOEM's Environmental Studies Program Information System (EPSIS). These included the Ecospatial Information Database, and the North, Central, and Southern Atlantic data syntheses. Some members of the Study Team had participated in some of these efforts and thus had information on the data sources. Other BOEM projects such as the Pacific coast data synthesis and compendium of avian information are still ongoing. While they are not yet available, they are expected to become available for the next phase of this project. The third major source of information was from the team's previous experience and familiarity with data sources from all planning areas. This experience was augmented with web-based data searches using conventional search engines. The data sources were categorized in terms of their ecological component(s) and parameters; the areal extent, and whether the data were in Geographical Information System (GIS) format (Table A-1). Verification of data quality will be evaluated once the analytical method and input data requirements have been finalized in an upcoming phase of this project.

Over 60 data sources were identified (Table A-1). They represent compilations from Federal agencies including BOEM, NOAA, U.S. Geological Survey, U.S. Army Corps of Engineers, and U.S. Fish and Wildlife Service (USFWS); State agencies such as South Carolina Department of Natural Resources; international collaborations such as the Avian Knowledge Network and the International Commission for Conservation of Atlantic Tunas; and non-governmental organizations such as the Nature Conservancy, Census of Marine Life, ReefBase and International Union for Conservation of Nature. Some sources, such as the Multipurpose Marine Cadastre, consolidate a multitude of individual datasets. Some current studies such as BOEM's Atlantic OCS Avian Compendium and the Ecospatial database were not yet available but represent excellent sources of information.

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Table A-1: Sources of Existing Information

Related Ecological Component(s)	Information Source	Description	Areal extent	Parameters	In GIS format?	Data availability (in house, on line)
Coastal and Marine Avian	eBird – available through Avian Knowledge Network http://www.avianknowledge.net	Birder sightings from around the hemisphere throughout the year. Each record includes a count, effort information, and information on whether all species are being reported. Data are vetted through the eBird Quality Control process.	Worldwide. Mostly terrestrial and coastal observations but a small number of pelagic observations	Abundance data for all bird species	yes	Online – available for all to use
Coastal Avian	International Shorebird Survey http://www.avianknowledge.net	Periodic counts of shorebirds (plovers, sandpipers and allies), principally during northward and southward migration periods.	Worldwide	Abundance Data focusing on shorebird species	yes	Permission needed to use
Coastal Avian	Audubon Coastal Bird Survey http://gulfoilspill.audubon.org/audubon-coastal-bird-survey	Costal bird surveys counting birds from Florida to Texas	Coastal areas from Florida to Texas	Counts of Coastal Birds	?	Report available online
Coastal Avian	Christmas Bird Counts http://birds.audubon.org/christmas-bird-count	Wintering Coastal Bird Data	North America – not just limited to coast, but many coastal counts	Counts of winter birds along coast	yes	Must be purchased from Audubon
Coastal Avian	North American Breeding Bird Surveys http://www.mbr-pwrc.usgs.gov/bbs/	Breeding Bird Coastal Bird Data	North America – not just limited to coast, but many coastal counts	Counts of breeding birds along coast	yes	yes
Coastal Avian	Northern California Coastal Waterbird Survey https://sites.google.com/site/coastalsurvey/home	Survey of Heron, egret, and cormorant nesting sites on California's northern and central coast	Northern and central California	Coastal nesting locations	?	? Contact John Sterling 530.908.3836
Coastal Habitat	NOAA Office of Response and Restoration-Environmental Sensitivity Indices (ESI) (http://response.restoration.noaa.gov/orr_search.php?keywords=ESI&submit=Go	Compilation of standardized data to map sensitivity of shorelines, related biological resources and services provided to humans to spilled oil;	US	Marine mammal, bird, sea turtle, fish, shellfish, coral, SAV	yes	On line
Coastal Habitat, Marine Habitat	USGS usSEABED Coastal & Marine Geology Program (http://walrus.wr.usgs.gov/usseabed/index.html)	Provides data on sediment and rock distributions in waters off US (Atlantic margin, Gulf of Mexico, Pacific margin with upcoming publication in Alaska)	US	Seabed geology	yes	On line
Coastal Habitat, Marine Habitat, Marine Fauna	The Nature Conservancy Northwest Atlantic Marine Ecoregional Assessment (TNC NAM ERA) (http://www.nature.org/ourinitiatives/regions/northamerica/areas/easternusmarine/explore/index.htm)	Ecoregional assessment framework for Cape Hatteras, NC to northern limit of Gulf of Maine and out to continental shelf/slope; geodatabase, GIS data, decision support tool for human uses, economics and biodiversity	US	Report and links to human use and GIS maps of: Sea floor habitats; coastal and estuarine habitats; marine habitats; large pelagic fish; marine mammal and sea turtles; shore and seabirds; physical oceanography	yes	On line
Coastal Habitat, Marine Habitat, Marine Fauna	Two reference databases and oceanographic resources synthesis developed for the former MMS Office of Alternative Energy Programs http://www.data.boem.gov/PI/PDFImages/ESPIS/5/5139.pdf	Extensive databases and synthesis reports for describing biological, chemical, geological and physical oceanography, as well as socio-economic effects of renewable energy infrastructure	U.S. Atlantic and Pacific OCS	To be determined	yes	Report on line; database to be published by BOEM

Related Ecological Component(s)	Information Source	Description	Areal extent	Parameters	In GIS format?	Data availability (in house, on line)
Commercial and recreational fishery landings.	The Fisheries Statistics Division of the National Marine Fisheries Service (NMFS). http://www.st.nmfs.noaa.gov/st1/html	Domestic commercial and recreational fishery landings: fish and shellfish landed and sold in the 50 states by U.S. fishermen; do not include landings made in U.S. territories or by foreign fishermen.	Coastal US all 50 states	Pounds and dollar value of commercial landings by years, months, states and species beginning in 1990. Other data from 1950.	Numbers. easily downloaded in tabular format	
Electromagnetic frequencies	NOAA Geophysical Data Center- Geomagnetic Data and Models http://www.ngdc.noaa.gov/geomag/geomag.shtml	Geomagnetic Data and Models, calculators, maps, and database	global	EMF	yes	On Line
Gulf of Mexico hydrocarbon seeps.	Actual lat/long coordinates of all 48 seeps in hand	Geographic locations of all seeps	Site specific	Location and identifcation of HAPCs	No but can be converted.	
Impacts, shipping traffic, Marine Mammals	Large whale ship strike website http://www.nmfs.noaa.gov/pr/shipstrike/	Various reports and data regarding large whale ship strikes	US	Impacts, shipping traffic, Marine mammals	no	On line
Impacts, shipping traffic, Marine Mammals	North Atlantic right whale sighting survey and sightings advisory system http://www.nefsc.noaa.gov/psb/surveys/	Latest right whale sightings data and information	U.S. Atlantic coast	Impacts, shipping traffic, marine mammals	no	On line
Marine Avian	Programme Integre des Recherches sur les Oiseaux Pelagiques (PIROP)	At-sea transect surveys of seabirds. ECSAS is the more recent program; PIROP the older initiative.	Pelagic Areas of Canada	Abundance data on pelagic species	yes	Permission needed from Canadian Wildlife Service
Marine Avian	Cetacean and Seabird Assessment Program http://www.avianknowledge.net/content/datasets/projects/csap	At-sea transect surveys of seabirds. CSAP is the more recent program; Manomet Offshore the older initiative.	Pelagic areas of the United States	Abundance data on pelagic species	yes	Permission needed from Manomet Center for Conservation Science
Marine Avian	Eastern Canadian Seabirds at Sea	At-sea transect surveys of seabirds. ECSAS is the more recent program; PIROP the older initiative.	Pelagic Areas of Canada	Abundance data on pelagic species	yes	Permission needed from Canadian Wildlife Service
Marine Avian	Texas Pelagics Bird Trip Archives http://www.texaspelagics.com/	Trip reports from Texas Pelagic Bird Surveys	Pelagic areas of the Texas portion of the Gulf of Mexico	Counts of Pelagic Birds	no	Reports available online
Marine Avian	USGS Alaska Science Center http://alaska.usgs.gov/science/biology/nppsd/products.php	Database of pelagic seabird numbers	Northern Pacific Ocean	Counts of coastal and Pelagic Birds	yes	Can be ordered on CD
Marine Avian	Alabama Pelagic Bird Records http://www.aosbirds.org/pelagicrecords.php	Incidental observations of Pelagic species in Alabama waters	Pelagic areas of Alabama	Incidental Counts	no	Online
Marine Avian	CWS Labrador Sea Survey http://www.bio.gc.ca/monitoring-monitorage/azomp-pmzao/labrador/bird-oiseaux-eng.htm	Counts of Seabirds	Labrador Sea of between Canada and Greenland	Pelagic Bird Counts	?	Contact CWS
Marine Fauna	Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP) http://seamap.env.duke.edu/ MGET= http://code.env.duke.edu/projects/mget NODC: http://www.nodc.noaa.gov/ OBIS-USA (U. S. node of the international OBIS (iOBIS): http://dbmuseblade.colorado.edu/ObisUsaTest/portal/	Geospatial database for global marine mammals (including Marine Mammal data archive) , seabirds and sea turtle data. MGET = Marine Geospatial Ecology Tools;	global	Birds, Marine mammals, sea turtles	yes	On line

Related Ecological Component(s)	Information Source	Description	Areal extent	Parameters	In GIS format?	Data availability (in house, on line)
	BoundingBox.php (Currently a beta test site, to will be replaced with a permanent one). iOBIS: http://www.iobis.org/ IOOS:http://www.pacioos.org/biodata (gateway link) http://oos.soest.hawaii.edu/erddap/categorize/ioos_category/biology/index.html (link to the referred site when using gateway link) .					
Marine Fauna	Barcode of life data systems http://www.marinebarcoding.org/	New species from census of marine life	global	Invertebrates, fish, marine mammals, birds, sea turtles	yes	On line
Marine Fauna	NOAA's coral reef information system http://coris.noaa.gov/	Various databases and information on reefs	US	Coral reefs	yes	On line
Marine Fauna	NOAA- stranding networks by region http://www.nmfs.noaa.gov/strandings.htm	Stranding reports and information in Northeast, Northwest, and Southeast regions	US	Marine mammals	no	On line
Marine Fauna, Climate Data	U.S. GLOBal Ocean ECosystems Dynamics http://www.usglobec.org/data.php	multi-disciplinary research program to examine the potential impact of global climate change on ocean ecosystems	Georges Bank, California Current off Oregon and Northern California, Coastal Gulf of Alaska	Zooplankton; marine fish	yes	On line
Marine Fauna, Habitat, Coastal Habitat, Acidification	USGS Coastal and Marine Program http://marine.usgs.gov/find.html	Comprehensive set of data sources. Separate databases for three regions, St. Petersburg = Gulf of Mexico; Menlo Park, CA = Pacific; Woods Hole, MA = Atlantic	US	Climate change, acidification, benthic habitat, sea turtles, etc. etc…	yes	Online
Marine Fauna, Marine Flora	Census of Marine Life http://www.iobis.org/mapper/ report = http://www.coml.org/pressreleases/census2010/PDF/Highlights-2010-Report-Low-Res.pdf	Database, maps, information re: marine census	global	Phytoplankton, zooplankton, fish, corals, marine mammals, sea turtles, sea birds	yes	On line
Marine Fauna, Marine Habitats, Acidification	Biological and Chemical Oceanography Data Management Office http://osprey.bcodmo.org/affiliation.cfm geospatial map = http://mapservice.bco-dmo.org/mapserver/maps-ol/index.php	Links to many programs, parameters, and databases including: CAMEO = Comparative Analysis of Marine Ecosystems Organizer; Deep-water estuaries management program; Analysis of zooplankton community dynamics; Ocean acidification; Integrated Marine Biogeochemistry Ecosystem Research - US	global	Zooplankton, deep water habitats, ocean acidification	yes	On line
Marine Fauna,Threatened and Endangered Species (T&E)	NOAA Fisheries Office of Protected Resources http://www.nmfs.noaa.gov/pr/	This site provides the official U.S. Federal list of T&E species.	All U.S. waters within the Exclusive Economic Zone (EEZ)	Species are broken down into six categories: endangered, threatened, candidate species, and species of concern	no	No
Marine Fish	NOAA's Essential Fish Habitat (EFH) Mapper (http://sharpfin.nmfs.noaa.gov/website/EFH_Mapper/map.aspx)	Includes EFH, habitat areas of particular concern (HAPCs),	Gulf of Mexico, New England/Mid-Atlantic, North Pacific, Pacific, South Atlantic, and Western Pacific	EFH species	yes	On line

Related Ecological Component(s)	Information Source	Description	Areal extent	Parameters	In GIS format?	Data availability (in house, on line)
Marine Fish	Northeast Regional Stock Assessment Workshop (SAW)/ Stock Assessment Review Committee (SARC) Reports http://www.nefsc.noaa.gov/nefsc/saw/	Formal scientific peer-review stock assessments for fish stocks in the offshore US waters of the northwest Atlantic. Biological data Commercial fish species. Species/stock specific.	US waters of the northwest Atlantic	Marine and estuarine fish	no	On line
Marine Fish	SouthEast Data, Assessment, and Review (SEDAR) Reports http://www.sefsc.noaa.gov/sedar/Index.jsp	Fishery stock assessments in the South Atlantic, Gulf of Mexico, and US Caribbean. Biological data Commercial fish species. Species/stock specific	US waters of South Atlantic, Gulf of Mexico, and Caribbean	Marine fish	no	On line
Marine Fish	Transboundary Resources Assessment Committee (TRAC) Status Reports and Reference Documents http://www2.mar.dfo-mpo.gc.ca/science/trac/TRAC.html	Fishery stock assessments/status updates for shared resources across the USA Canada boundary in the Gulf of Maine-Georges Bank region. Biological data Commercial fish species. Species/stock specific	USA Canada boundary: Gulf of Maine-Georges Bank region	Marine fish	no	On line
Marine Fish	Species Information System Public Portal https://www.st.nmfs.noaa.gov/sisPortal/sisPortalMain.jsp	SIS collects and manages regional and national data across NMFS offices. The data housed within SIS includes the up-to-date information on the status of managed stocks and stock assessment results, and other important associated information.	US waters	Marine fish	yes	On line
Marine Fish, Human use	Marine Recreational Fisheries Statistics Survey (MRFSS) http://www.st.nmfs.noaa.gov/st1/recreational/queries/index.html	Estimated recreational catch. Biological data	US waters, by sub-region and state	Marine recreational fish	no	On line
Marine Fish, Human use	National Marine Fisheries Service (NMFS) Commercial Fisheries Landings http://www.st.nmfs.noaa.gov/st1/commercial/index.html	Programs to query commercial fishery data bases and summarize domestic commercial landings in several formats. Biological data	US waters	Commercial fishing, marine fish	yes	On line
Marine Fish, Marine Habitat	Atlantic State Marine Fisheries Commission Stock Assessment and Peer Review Reports http://www.asmfc.org/	Fishery stock assessments of 24 Atlantic coastal fish species or species groups Biological data Species/stock specific	Atlantic coast Maine to Florida	Marine fish, marine habitat	no	On line
Marine Fish-Tuna	International Commission for the Conservation of Atlantic Tunas Stock Assessments http://www.iccat.es/en/assess.htm	Internationally managed species: tunas and tuna-like species in the Atlantic Ocean and adjacent seas. Biological data Atlantic bluefin, skipjack, yellowfin, albacore and bigeye tuna; swordfish; billfishes (white marlin, blue marlin, sailfish and spearfish); mackerels (spotted Spanish mackerel and king mackerel); and, small tunas (black skipjack, frigate tuna, and Atlantic bonito)	Atlantic and adjacent oceans	Marine and pelagic fish	no	On line

Related Ecological Component(s)	Information Source	Description	Areal extent	Parameters	In GIS format?	Data availability (in house, on line)
Marine Flora- Mangroves	mangroves http://www.marineclimatechange.com/marineclimatechange/bluecarbon_2_files/Girietal2011.pdf	Status and distribution of Mangrove forests of the world using earth observation satellite data	global	mangroves	yes	On line
Marine Flora- Seagrass	Seagrass Atlas http://www.unep-wcmc.org/marine/seagrassatlas	Seagrass maps	global	seagrass	yes	On line
Marine Flora, Marine Fauna	A Global change master directory portal for the Global Ocean Ecosystem Dynamics Programme – Aquatic Ecosystems http://gcmd.gsfc.nasa.gov/KeywordSearch/Keywords.do?Portal=globec&KeywordPath=Parameters%7CBIOSPHERE%7CAQUATIC+ECOSYSTEMS&MetadataType=0&lbnode=mdlb2	Databases for: Benthic, coastal, demersal, marine, pelagic, plankton, reef, wetlands	global	Benthic, coastal, demersal, marine, pelagic, plankton, reef, wetlands	no	On line
Marine Flora, Marine Fauna	NOAA –Office of Protected resources Unusual Mortality Events http://www.nmfs.noaa.gov/pr/health/mmume/	Unusual mortality events regarding US protected species	US	Marine mammals, fish, algal blooms	no	On line
Marine Habitats-Bathymetry	NOAA National Geophysical Data Center Bathymetry and global relief http://www.ngdc.noaa.gov/mgg/bathymetry/relief.html	Database for bathymetry maps	global	Bathymetry, marine geophysical habitat	yes	On line
Marine Habitats-Bathymetry	http://www.ngdc.noaa.gov/mgg/mggd.html	Marine geology and geophysics	global	bathymetry	yes	On line
Marine Habitats Marine Fauna	Groundfish Essential Fish Habitat EIS (http://marinehabitat.psmfc.org/). GIS map = http://sharpfin.nmfs.noaa.gov/website/EFH_Mapper/map.aspx	Information and geospatial data on marine features, water depth, latitude, maps of estuaries, shoreline biogenic habitat (e.g., corals, kelps) from Washington state to California southern border	US	EFH species and managed areas	yes	On Line
Marine Habitats, Marine Fauna	PaCOOS West Coast Habitat Portal (http://pacoos.coas.oregonstate.edu/MarineHabitatViewer/viewer.aspx)	Interactive web mapping application to display and investigate marine geological, oceanographic, and fisheries datasets within the California Current Large Marine Ecosystem	US Pacific	GIS maps for: Marine managed areas, Fish, Invertebrates, kelp, sea birds, sea floor habitat	yes	On line
Marine Habitats, Marine Fauna	BOEM EcoSpatial Information Database (ESID) (created by team led by AMEC Earth & Environmental)	Geospatial database with geographic access to documents and GIS files for geology, pelagic ecology of infauna, meiofauna, demersal fishes, coral and hardbottom and seagrass	Atlantic OCS	To be determined	yes	Publication by BOEM imminent
Marine Habitats, Marine Fauna, Marine Flora, impacts	Multipurpose Marine Cadastre http://www.marinecadastre.gov/default.aspx	Integrated marine information system that provides ocean information including offshore boundaries, infrastructure, human use, biological and other data sets Designed for an ocean planning tool. Contains regional data portals with multiple databases. Some still in development.	US	Marine habitats, fish, kelp, sea grass, physical oceanography	yes	On line

Related Ecological Component(s)	Information Source	Description	Areal extent	Parameters	In GIS format?	Data availability (in house, on line)
Marine Habitats; Physical Oceanography	U.S. IOOS (Integrated Ocean Observing System) http://www.ioos.gov/data/welcome.html	Tool for tracking, predicting, managing, and adapting to changes in ocean, coastal and Great Lakes environment	US waters, has a global link as well	Marine habitat; physical oceanography	yes	On line
Marine Habitats- sea bottom substrate	dbSEABED: An Information Processing System for Marine Substrates http://instaar.colorado.edu/~jenkinsc/dbseabed/	Databases including "Core Navigator" maps used for offshore resources and defense acoustic research	US	Sea bottom substrate	yes	On Line
Marine Habitats-Reefs	Reefbase – Global Information System for coral reefs http://www.reefbase.org/main.aspx	ReefGIS is a ReefBase's online Geographic Information System was developed to display coral reef-related data and information on interactive maps on web browsers.	Global	Thematic datasets contain all records for a specific topic (i.e. coral bleaching, monitoring, mpa's, etc.) for the entire world or by region	yes	On line
Marine Mammals	NOAA Office of Protected Resources http://www.nmfs.noaa.gov/pr/species/turtles/	Marine Mammal stock assessments, 5-year reviews, recovery plans, critical habitats by species or region	All US waters to EEZ	Marine Mammals & Sea turtles	no	On line
Marine Mammals/Sea Turtles	Florida Fish and Wildlife Conservation Commission http://www.myfwc.com/research/wildlife	Sea turtle (threats and nesting), right whale, and manatee species and habitat information	Florida state waters	Sea turtles and marine mammals	no	On line
Marine Plankton	NMFS Programs = COPEPOD, COPEPODITE, NAUPLIUS http://www.st.nmfs.noaa.gov/plankton/content/index.html	global plankton database of phytoplankton data and zooplankton data sampled globally	global	Ichthyoplankton, phytoplankton, zooplankton	yes	On line
Marine Plankton	Cooperative Zooplankton Dataspace http://oceaninformatics.ucsd.edu/zooplankton/	US Pacific Zooplankton database	California	zooplankton	yes	On line
Marine Productivity	CSA 1990, 1991, MMS 2010	Based on primary production (metric tons/year) from phytoplankton	All OCS planning areas	phytoplankton	no	Unclear
Sea Turtles	South Carolina Department of Natural Resources Marine Turtle Conservation Program http://www.dnr.sc.gov/seaturtle/	Sea turtle threats and nesting information	South Carolina state waters	Sea turtles	no	On line
Sea Turtles	USACE Sea Turtle Data Warehouse http://el.erdc.usace.army.mil/seaturtles/index.cfm	Information by species and region regarding dredging interactions with turtles, takes by region, Biological Assessment Opinions	Gulf of Mexico, North Atlantic, and South Atlantic	Sea turtles, dredging	no	On line
Sea Turtles	Seaturtle.org http://www.seaturtle.org/tracking/explorer/	Sea Turtle Tracking data by species and region (actual track lines available)	US waters to EEZ	Sea turtles, satellite tracking	yes	On line
Sea Turtles	Seaturtle.org http://www.seaturtle.org/nestdb/	Sea turtle nest monitoring data	North Carolina to Texas	Sea turtle nesting site data	yes	On line
Sea turtles	Sea Turtle Stranding and Salvage Network (STSSN) http://www.sefsc.noaa.gov/species/turtles/strandings.html	NOAA's The Sea Turtle Stranding and Salvage Network (STSSN) was formally established in 1980 to collect information on and document strandings of marine turtles along the U.S. Gulf of Mexico and Atlantic coasts. The network, which includes federal, state and private partners, encompasses the coastal areas of the eighteen-state region from Maine to Texas, and includes portions of the U.S. Caribbean.	U.S. Gulf of Mexico and Atlantic coasts.	Using online reports, user may obtain basic summarized stranding information from 1986-2007. For years 2008- use the Weekly Reports	Unknown. Site was out of service at the writing of this entry. Data are at minimum tabular thus convertible to GIS-	

Related Ecological Component(s)	Information Source	Description	Areal extent	Parameters	In GIS format?	Data availability (in house, on line)
					Fechhelm	
Shipping traffic; Marine Mammals/Sea Turtles	World Meteorological Organization Voluntary Observing Ships Scheme; http://www.vos.noaa.gov/vos_scheme.shtml)	Vessel/shipping tracks and data	US waters	Marine mammals and sea turtles impacts	yes	On line
Shipping traffic; Marine Mammals/Sea Turtles	American Association of Port Authorities http://www.aapa-ports.org	US Port use Vessel/shipping	US	Marine mammals and sea turtles impacts	yes	On line
Shipping traffic; Marine Mammals/Sea Turtles	World Port Index http://www.nga.mil/portal/site/maritime/	Vessel/shipping	global	Marine mammals and sea turtles impacts	yes	On line
Threatened and Endangered Species (T&E)	International Union for Conservation of Nature (IUCN) Redlist http://www.iucnredlist.org/	The internationally accepted and definitive listing of threatened species worldwide.	Global	Species are broken down into six categories: critically endanger, endangered, vulnerable, near threatened, least concern.	no	
Wetlands	US Fish and Wildlife Service Wetlands Mapper http://www.fws.gov/wetlands/Data/Mapper.html	Wetlands and deepwater habitats prepared from the analysis of high altitude imagery. Wetlands are identified based on vegetation, visible hydrology and geography.	Coastal US	Wetlands	yes	

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APPENDIX B: EXISTING APPROACHES TO ESTIMATING ENVIRONMENTAL SENSITIVITY

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The Study Team identified 12 methods as potentially suitable for use in this project. Each is described in detail in the following sections, along with how each met study evaluation criteria. A table summarizing these 12 methods is provided in Table B-1. Each evaluation includes a description of the main concept of the approach, input data required, output of the model, suitability of the approach to the aims of the BOEM project, and a summary.

B.1 BOEM RELATIVE ENVIRONMENTAL SENSITIVITY ANALYSIS (RESA)

The BOEM relative ESA (BOEMRE 2010) was developed to satisfy the requirements of Section 18(2)(g) of the OCSLA. Environmental sensitivity is assessed for each of BOEM's 26 OCS planning areas. The ESA is a required component in BOEM's 5-year oil and gas leasing program decisions. The ESA method assesses the relative environmental sensitivity of OCS planning areas by aggregating component responses of selected habitats and faunal groups related to the potential adverse effects of oil and gas leasing activities, and incorporating system responses for marine primary productivity and climate change.

Input data are grouped into four model components: coastal habitats, marine habitats, marine fauna, and marine primary productivity (Table B-1). Environmental consequences related to oil and gas leasing are considered for three impact-causing factors: (1) spilled crude oil, (2) anthropogenic sound, and (3) physical disturbance. Climate change information is also included as a factor in the analysis. Data are derived from a variety of reports, publications, and data sources.

The output format is in sensitivity scores that are reported for all 26 OCS planning areas and for each model component. The overall ESA result is a listing of planning areas grouped into four classes: most, more, less, and least sensitive.

The original method, NOAA's ESI (NOAA 1997), was developed to assess the relative environmental sensitivity of shorelines to oil spills. This is the existing purpose-built model. It was designed to satisfy the requirements of the OCSLA. Recent modifications have substantially expanded and improved the method. The analysis now incorporates the marine environment, includes consideration of sound and physical disturbances, and includes marine productivity and climate change as factors in the analyses.

Nonetheless, BOEM recognizes the shortcomings of this existing model. The full range of environmental resources within OCS planning areas is not adequately represented in the current method. Sensitivity to activities associated with minerals extraction and offshore alternative energy leasing are not considered in this method. Also, ambiguity in the definition of "environmental sensitivity" in the OCSLA has resulted in the perception by some parties that the method results are counterintuitive. This ambiguity results because "sensitivity" can be interpreted as either "vulnerability to potential impacts" or "resilience."

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Table B-1: Details of the BOEM ESA Method

Environmental Resource Inputs		Environmental Consequences Inputs			Analysis Description		
Components	**Data**	**Oil spills**	**Sound**	**Physical disturbance**	**Scoring and Computation**	**Model output**	**Comments**
Coastal habitats	Data housed in NOAA ESI database (NOAA 2002).	X			NOAA ESI shoreline type classification: ESI Scores from 1 to 10 in order of increasing sensitivity of ten rank-ordered shoreline habitat types. ESI values weighted by length of line segment (linear amount of habitat type), and a weighted average computed for each planning area.	Highest score = highest sensitivity	
Marine habitats	Various reports, publications and data sources.	X		X	A total of 11 marine habitats were assessed. Selected Benthic (6), Pelagic (3), and Designated (2) habitat types were scored (1–3, low to high) for relative abundance; the habitat abundance values were then multiplied by an expected sensitivity (to oil impacts: spills, disturbance) impact coefficient (rank ordered, 2–4, low to high); the habitat products were summed within each planning area, and a value of 1 was added for each federally designated area	Highest score = highest sensitivity	
Marine fauna: birds	Various reports, publications and data sources.	X			Two categories: (1) marine and (2) coastal birds. Abundance scores assigned for each planning area: Low=1, Moderate=3, and High=5. The same sensitivity coefficient (5) was applied for all planning areas and both bird groups. Each ESA-listed bird species present in a planning area was given a value of 1. Scores computed by summing: (1) the product of marine bird abundance and sensitivity values, (2) the product of coastal bird abundance and sensitivity values, and (3) the number of ESA-listed species.	Highest score = highest sensitivity	Same impact coefficient (5) was assigned to all

Environmental Resource Inputs		Environmental Consequences Inputs			Analysis Description		
Components	**Data**	**Oil spills**	**Sound**	**Physical disturbance**	**Scoring and Computation**	**Model output**	**Comments**
Marine fauna: fish	Various reports, publications and data sources.				Estuarine, diadromous, and marine fish were assessed. Estuarine and marine shellfish were also assessed. ESA-listed species were assigned a value of 5 for threatened species, and 10 for endangered species. Based on Federal marine fisheries stock assessments, each stock listed as overfished and/or subject to overfishing in a planning area was given a value of 1. Abundance scores assigned for each planning area based on commercial landings data: Low=5, Moderate=25, and High=50. Overall scores computed by summing assigned scores within each planning area.	Highest score = highest sensitivity	No impact coefficient was assigned
Marine fauna: mammals	NMFS and USFWS marine mammal stock assessment reports.	X	X		Marine mammals listed as depleted under Marine Mammal Protection Act (MMPA) were assigned a value of 1; ESA-listed threatened species were given a 5, and endangered species a 10. Species deemed highly susceptible to oil spills were assigned a value of 10, and all other species were given a 5 for oil spill susceptibility. Species were scored by susceptibility to sound as: Low=1, Moderate=5, and High=10. Overall scores were computed by summing values within species, and then totals across species for each planning area.	Highest score = highest sensitivity	

Environmental Resource Inputs		Environmental Consequences Inputs			Analysis Description		
Components	**Data**	**Oil spills**	**Sound**	**Physical disturbance**	**Scoring and Computation**	**Model output**	**Comments**
Marine fauna: sea turtles	NMFS and USFWS Recovery Plans, 5-Year Reports, and Status Reviews.	X	X		Sea turtle presence values were assigned in 3 categories: (1) species rarely reported in a planning area were assigned a value of 1, (2) species with seasonal presence were given a 2, and (3) those found year-round or with nesting sites in a planning are were given a 3. ESA-listed species were assigned a value of 5 for threatened species, and 10 for endangered species. All species were assigned a value of 10 for sensitivity to oil spills, and 5 for sensitivity to sound. Scores were computed for each species by multiplying the presence value by the sum of: ESA-listing, oil sensitivity, and sound sensitivity values. Overall scores for each planning area were computed by summing the results across species.	Highest score = highest sensitivity	Same impact coefficient (15; spills + sound) was assigned to all
Marine fauna total score	N/A	N/A	N/A	N/A	Scores for each of the four faunal groups were normalized (using min-max normalization) within the range of 0-1; the overall marine fauna score was computed by summing the group scores to obtain values for each planning area within the range of 0-4.	Highest score = highest sensitivity	
Marine productivity	CSA 1990, CSA 1991	X			Primary productivity was included as mean areal production (metric tons/acre/year) for each planning area.	Highest score = highest sensitivity	No impact coefficient was assigned
Climate change and ocean acidification	Karl et al. 2009	N/A	N/A	N/A	An impact coefficient was assigned to each planning area based on relative magnitude of effects from climate change and ocean acidification. Values were assigned in 3 categories: Low=1, Moderate=1.5, and High=2.		

Environmental Resource Inputs		Environmental Consequences Inputs			Analysis Description		
Components	**Data**	**Oil spills**	**Sound**	**Physical disturbance**	**Scoring and Computation**	**Model output**	**Comments**
Overall ESA ranking	N/A	N/A	N/A	N/A	Scores for each of the four ecological components (i.e., coastal habitats, marine habitats, marine fauna and marine productivity) were normalized within the range of 0-1; the overall ESA score was computed by summing the component scores, and multiplying those scores by the climate change coefficient to obtain values for each planning area. Overall ESA scores were not presented for each planning area. Instead, planning areas were grouped by rank-ordered scores into 4 groups: (1) most, (2) more, (3) less, and (4) least sensitive. Planning areas were assigned to groups above (most and more) and below (less and least) the mean; then further separated by scores within one standard deviation from the mean score.	Planning areas grouped by “most,” “more,” “less,” and “least” sensitive.	Distinction between “less” and “least” groups is not explicitly described.

Since the method is based on aggregating component responses, it could be modified to include additional environmental resources and to address sensitivity to all activities for which BOEM has oversight responsibilities on the OCS. If this method is used as a basis for the project's "recommended method," scoring protocols and rationale should be carefully assessed and then further described to minimize subjectivity and increase transparency.

B.2 FISHERIES AND OCEAN CANADA CHARACTERIZATION AND RISK ASSESSMENT

The Fisheries and Ocean Canada (formerly Department of Fisheries and Oceans, [DFO]) is responsible for leading and facilitating all activities in or affecting estuarine, coastal, and marine waters. Canada's marine and coastal waters are geographically divided into five Large Ocean Management Areas. In collaboration with all stakeholders, management plans were developed for each Large Ocean Management Areas using an ecosystem management approach. Ecosystem-based management establishes objectives for various components of marine ecosystem structures and functions, rather than individual resources. This method uses a two-step process. First, significant ecosystem components are identified and ranked based solely on their ecological significance. Those of medium and high significance are then assessed based on the level of risk from stressors, both natural and human-induced.

The first step is analogous to a marine spatial planning exercise, where ecologically important areas are identified (called "Conservation Priorities" in Park et al. 2010) using a collaborative and science-based process. Four types of criteria are evaluated: "Ecologically and Biologically Significant Areas" (DFO 2004), "Ecologically Significant Species and Community Properties," "Depleted or Rare Species," and "Degraded Areas" (DFO 2007). In DFO terms, "significant" means that a species or habitat would be more highly affected by a perturbation than another species or habitat.

The identification of "Ecologically and Biologically Significant Areas" is based on the following ecosystem component characteristics (DFO 2004; DFO 2007):

- Uniqueness: the level to which species or features are rare, distinct, or unique, either regionally, nationally, or globally;
- Aggregation: the level to which individuals are grouped together during part of the year, or areas that provide an important life-history function; and
- Fitness consequences: the level to which life-history activities contribute to the reproduction and/or survival of a population or species.

The identification of "Ecologically Significant Species and Community Properties" involves examining characteristics that would have dire ecological consequences if eliminated.

"Depleted or Rare Species" are species that are at very low abundances compared to historical abundances and warrant special measures to ensure long-term recovery and survival. These species conform to those protected by regulation as threatened or endangered by the Canadian Government (Committee of Endangered Wildlife of Canada, in this case), or below a certain population threshold (in this case, the critical cautious boundary established by Canadian Science Advisory Secretariat, a peer review panel for DFO).

"Degraded Areas" are those where anthropogenic activity has severely decreased the natural ecosystem's structure and function.

Lists of areas meeting the four criteria were assembled and analyzed. In the case of the Placentia Bay-Grand Banks, scientists developed a process to sort through and prioritize areas in each category. Some of the issues encountered were:

1. How to treat coastal areas, which are not technically part of the LOMA;
2. Whether a species should be considered Depleted or Rare if inherently rare or not widespread, or if the rarity was caused by anthropogenic influences;
3. How best to define "degraded," either those resources identified by regulatory agencies, or additional areas based on characteristics such as size, source of degradation, or degree of impairment.

The next decision was how to combine the four lists so that the highest priorities were identified. In this case, the rationale behind each listing was taken into account. The number of reasons that a site met the criteria was used to define relative importance (DFO 2007). Adaptation of this method would require a similar, collaborative process to identify the sites with the highest importance (Conservation Priorities). The DFO has developed management goals ("conservation objectives") that stem directly from the criteria and rationale behind the site's listing.

The second step of this method characterized and analyzed the level of risk from human activities and other environmental stressors on the highest priority areas (Park et al. 2010). This process involved three phases:

1. Identify harmful activities or stressors. DFO has developed a list of human activities (e.g., types of fishing and harvesting, types of seabed and coastal alterations, and disturbances) and stressors (types of pollution, aspects of climate change, harmful species). Activities and stressors that affect each area were listed.
2. Characterize and analyze the risk for each activity or stressor.
3. Create a cumulative score based on all of the individual activities and stressors.

The level of risk is assessed based on two factors: the magnitude of interaction and sensitivity. The magnitude of interaction, assessed on a rank from 1-10 for each factor, takes into account four factors: the areal extent or overlap between the defined area and the harmful activity or stressor, likelihood of contact, duration, and intensity. Sensitivity in this method is defined as "the degree to which an adverse response may result from an interaction with the stressor or activity." Sensitivity is scored based on the severity and nature of the stressor. Sensitivity assessment considers both acute and chronic effects, as well as the importance of the site in the larger ecosystem. The scores for magnitude of interaction and sensitivity are combined for a score for "risk of harm." Areas can then be ranked based on the cumulative risk of harm scores.

The method was initially developed and tested in the Placentia Bay/Grand Banks large ocean management area in Newfoundland CA, and adapted by two other DFO regions (the Gulf of St. Lawrence and British Columbia). The method has been developed with considerable input from other scientists. Government-released publications have been issued, but the method has not been peer reviewed.

DFO is identifying Conservation Priorities for all five LOMAs based on this method. The risk assessment methodology has been adopted for the Placentia Bay/Grand Banks LOMA, as well as in the Gulf of St. Lawrence and British Columbia.

Some of the input data are readily available by managing organizations (threatened and endangered species, fisheries management areas) but much is based on scientific knowledge of individual areas. The method could be adapted to encompass BOEM OCS planning areas by combining information for smaller areas. Existing marine spatial planning information could be used.

The model output identifies conservation priorities and risk from both human activities and other stressors, effectively encompassing cumulative impacts. Sensitivity is part of the output. Results include a sensitivity analysis and can address climate change and cumulative impacts. Adaptation to the 26 OCS planning areas would require considerable effort in securing information and then working through the analytical process, not unlike the original Environmental Sensitivity Index.

This model meets many of the goals for the BOEM method, including an environmental sensitivity analysis and ability to address factors such as climate change and cumulative impacts. The method, while developed by research scientists, has not undergone peer review. It has not been used in the United States, so would need to be developed for all OCS planning areas.

B.3 MODELING APPROACHES: ECOPATH WITH ECOSIM AND ATLANTIS

Ecopath is a mass-balance food web model that analyzes ecosystems based on biomass flow through trophic levels. Additional modules include Ecosim, which allows simulation of changes to the system, and Ecospace, a GIS-based module allowing spatial analysis. The model was first introduced by Polovina (1984); since that time, the model has been continuously developed, with over 300 articles been published to date. The software is available from the project website (www.ecopath.org), along with tutorials, publications, and models.

The Ecopath model was originally developed to explore the effects of fishing and environmental disturbance. In theory, the model can be used to perform the following (Christiansen et al. 2005):

- Address ecological questions;
- Evaluate ecosystem effects of fishing;
- Explore management policy options;
- Analyze impact and placement of MPAs ;
- Predict movement and accumulation of contaminants and tracers (Ecotracer); and
- Model effect of environmental changes.
- The foundation of Ecopath is based on these two equations (in simplistic form):
    - Production = catch + predation + net migration + biomass accumulation + other mortality
    - Consumption = production + respiration + unassimilated food

The equations are linked in that predation in the production term is represented by consumption in the next higher trophic level. Multiple equations are developed for each functional group within an ecosystem, with ecosystem is defined as a three dimensional volume of water that is characterized by a distinct group of organisms or functional group. Ecosystems are established based on distance from shore, water depth, bottom type, etc. A functional group may be a species guild, a single species, or a cohort of species. Ecopath with Ecosim solutions quantify a snapshot of the biomass produced and consumed in each trophic level (Pauly et al. 2000; Christensen and Pauly 1992; Christensen and Walters 2004). Ecopath models are ecosystem-specific, and have been developed for over 120 areas (Ecopath 2011).

Ecopath model development requires several types of data inputs, including biomass, production: biomass ratio (or total mortality), consumption:biomass ratio (equivalent to instantaneous mortality), and ecotrophic efficiency (proportion of biomass that is used in the ecosystem). Data for three of these four parameters are sufficient to run the model (Christensen et al. 2005).

The Ecopath model is developed from biomass, catch, or abundance data; diet composition; mortality and consumption rates; and ecotrophic efficiency for each trophic level. Some of the data are derived from field studies (catch or abundance data) and others from the literature (production:biomass ratio, consumption:biomass ratio). Not all parameters are necessary; with sufficient input data, Ecopath can fill in missing data. The time period for input data is generally one year, although the model can accommodate both shorter (seasonal) and longer time periods.

The input data are used to develop an ecosystem-specific model (Christensen et al. 2005). The results of the Ecopath model can be fed into Ecosim, which simulates ecosystem response under different scenarios.

The model output can take several forms. A path diagram of the biomass flow among trophic levels is one type of output. Use of Ecopath with Ecosim can estimate changes from, for example, increasing harvesting rates, by developing two models and comparing results

The advantages of Ecopath with Ecosim are that it is widely used and has a broad constituency. The input data, at the broadest scale, are readily available. Christiansen et al. (2009) recently calculated fish biomass and catches for all of the LMEs using Ecopath with Ecosim models and several fish databases. In 2007, it was named one of the 10 biggest scientific breakthroughs in NOAA's 200-year history because it enhanced the understanding of complex marine ecosystems.

The Ecopath with Ecosim is fisheries-focused, which is limiting for this project. Furthermore, as a carbon-based model, it cannot accommodate non-carbon based elements such as protected species or habitats. Other disadvantages have been outlined in Balcom et al. (2011). Of particular concern for this project is that Ecopath with Ecosim does not consider habitat changes, which could be one of the effects of BOEM activities. Modeling populations of marine mammals has been difficult. In addition, parameters with high seasonal variability are not effectively incorporated in the model. Directly modeling cumulative impacts and climate change is not possible with the current model. Instead, multiple models would need to be created and then compared. The results, expressed in differences in biomass flow among trophic levels, would be difficult to interpret.

As an aside, the "sensitivity analysis" provided by Ecopath is an assessment of the sensitivity of the model to changes in the input data.

The wide acceptance of the Ecopath model is a positive. However, it currently does not meet all of requirements of the ideal method, especially seasonality, climate change, and cumulative impacts. The results would be difficult to present to the lay public.

Atlantis is another ecosystem model, differing from Ecopath in that it includes both non-biological elements (e.g., physical, economic, and social) as well as biological elements. Developed by Fulton (2003, 2005), the Atlantis model has been rated best in the world by the Food and Agriculture Organization. Atlantis is a three-dimensional ecosystem model that integrates physical, chemical, and biological dynamics. The model consists of a series of submodels solved simultaneously. Atlantis tracks nutrient flow (nitrogen and silica in most cases) through trophic levels. As a first step, three-dimensional polygons are delineated based on physical and biological properties such as depth, substrate, and biota. A model for each polygon's physical environment is developed, along with the hydrodynamic processes that predict flow to adjacent polygons. Within each polygon, models of biological processes (consumption, production, migration, predation, recruitment, mortality, etc.) are created for functional groups. The model considers lower trophic levels (e.g., invertebrates) as “biomass “pools,” but higher trophic levels involving vertebrates incorporate age and stock-assessment data. In the United States, the model has been developed for the northern Gulf of California current (Ainsworth et al. 2011) and Northeast Atlantic LME (Link et al. 2010), and is currently in development for the Chesapeake Bay (CSIRO 2011).

Atlantis is a three-dimensional ecosystem model that integrates physical, chemical, and biological dynamics. The model is a series of submodels solved simultaneously. Unlike the Ecopath model, Atlantis tracks nutrient flow (nitrogen and silica in most cases) through the trophic levels. As a first step, three-dimensional polygons are delineated based on physical and biological properties such as depth, substrate, and biota. A model for each polygon’s physical environment is developed along with the hydrodynamic processes that predict flow to adjacent polygons. Within each polygon, models of biological processes (consumption, production, migration, predation, recruitment, mortality, etc.) are created for functional groups. The model categorizes lower trophic levels (e.g., invertebrates) as “biomass pools,” but higher trophic levels involving vertebrates incorporate age and stock-assessment data.

Atlantis can also incorporate anthropogenic influences in its exploitation models. These models are most commonly used to evaluate fisheries management strategies by examining changes in fishing pressure and fishing techniques. However, they can also be used by simulating changes in pollution, coastal development, and broader scale influences such as climate change. A separate management model can be used to evaluate the effects of different regulatory and other management techniques.

The Atlantis model includes approximately 60 functional groups, encompassing pelagic invertebrates, epibenthic invertebrates, primary producers, and age-structured vertebrates. Once species are assigned to groups, no changes may be made. Input data include abundance, biomass, or catch data for each group and proportion of nitrogen. Biomass of vertebrates is divided into bone and other weight. The abundance of each group is tracked through the area over time, with nutrients (usually nitrogen or silica) used to measure flow among the trophic levels.

The model output is descriptive, showing spatial distribution of various species and nutrients. Models can be rerun and compare the effects various management and regulatory options. As a multispecies, multivariate method, it is a more comprehensive approach than the traditional single species stock assessments.

The Atlantis model is still under development. Expansion to all other BOEM OCS planning areas and refinement of the model to incorporate sensitivity to all BOEM activities would be a substantial effort. The advantage of this method is that it incorporates physical, hydrographic, and biological data in three dimensions. Since NOAA is spearheading development efforts, it has some Federal agency acceptance. Atlantis does not appear to be able to accommodate special regulatory considerations such as endangered species.

Atlantis is a multi-dimensional, multi-species model that describes ecosystem conditions. Its primary purpose is to explore fisheries management alternatives, but could be adapted to evaluate BOEM activities and from that, sensitivity. Application of Atlantis would require model development groundtruthing for all OCS planning areas, followed by simulation of BOEM activities.

B.4 LARGE MARINE ECOSYSTEMS METHOD

The United Nations Environment Programme LME method (Sherman and Hempel 2009) is a global system specifically designed for monitoring, assessing, and management of marine ecosystems. The method integrates five predetermined categories (modules) of summarized data for each previously delineated LME.

The LME system consists of 64 separate ecosystems globally (11 ecosystems in U.S. waters: East Bering Sea, Gulf of Alaska, California Current, GOM, Southeast U.S. Continental Shelf, Northeast Continental Shelf, Beaufort Sea, Chukchi Sea, West Bering Sea, Insular Pacific-Hawaiian, and Caribbean Sea). The ecosystem's boundaries are delineated based on fisheries stocks, land-based runoff, and oceanfront current systems, among other parameters. The LME divisions were based on what was deemed to be an appropriate size for management, assessment, and analysis. For each LME, data are categorized into five modules (biological productivity, fish and fisheries, pollution and health, socioeconomics, and governance) and summarized with discussion, tables, and figures. The source document is a voluminous report containing four papers detailing 1) the LME approach, 2) fisheries, 3) warming trends and biomass, and 4) land-based sources of nutrients (Sherman and Hempel 2009). Within these reports are many useful summaries, time series and summary plots, and in-depth discussions of the above parameters. The remaining part of the report contains a summary and discussion of the five modules in each of the 64 global LMEs.

This model requires input data for biological productivity, fish and fisheries, pollution and health, socioeconomics, and governance. There is no distinct numerical output from the model because it is mainly descriptive of entire ecosystems (e.g., GOM, California Current) that encompass entire fishery stocks, coastal front systems, primary productivity, etc. The geographic delineations (LMEs) of this model are very useful for looking at interrelated parameters in an area size helpful for large-scale impact analysis (e.g., oil spill, acoustic, fishery stocks, climate change). The output for this model is a series of "briefs," or summaries for each of the LMEs. Each brief includes data summaries and figures for each of the five indicators (biological productivity, fish and fisheries, pollution and health, socioeconomics, and governance). A description of each module output is listed below.

Biological Productivity: This indicator includes three sections (ocean fronts, sea surface temperature, and chlorophyll and primary productivity). The ocean front data output enables analyses for oil spill management, acoustic propagation, upwelling and primary productivity, fisheries stock assessment, etc. The sea surface temperature discussion includes time series figures (1957 – 2006), which are linked to fisheries management (i.e., exploitation status) for each LME. The chlorophyll and primary productivity discussion estimates depth integrated primary productivity based on chlorophyll pigment concentration data, and photosynthetically active radiation calculated as in Bouvet et al. (2002).

Fish and Fisheries: The Sea Around Us website provides completed time series figures for multiple fisheries parameters (i.e., commercial groups, functional groups, fishing country). There is a total reported landings discussion and time series plots from 1950 through 2004 along with the value of reported landings time series plots from 1950 through 2004; the primary productivity required to support reported landings; mean tropic level (Marine Trophic Index) and fishing in balance index time series plots; stock-catch status plots (proportion of developing, fully exploited, overexploited, and collapsed fisheries by number of stocks and by catch biomass from 1950 through 2004) (Sea Around Us 2011).

Pollution and Ecosystem Health: This indicator focuses mainly on dissolved inorganic nitrogen and dissolved inorganic phosphorous as the proxy for ecosystem health and includes discussion on pollution sources, types, levels, rate of change, areal extent of pollution zones, bioaccumulation, and habitat and community modification. The latter includes discussion on biodiversity, habitat types within the ecosystem, condition/status of specific habitats and their stressors, sea level rise, rate of coastal land loss, stress types, species specific responses to habitat loss, and unique habitats for endangered species.

Socioeconomics: This indicator involves the human population in coastal areas of LMEs (including those for foreign border countries), economic assets, commercial land values, oil and gas production (percent of U.S. production), tourism, rate of loss of habitats and public use value of loss estimates.

Governance: This indicator concerns Federal, State, and international programs and policies in place to protect, restore, and enhance the LME.

The plots presented for each LME are easily interpreted (color-coded maps and figures), and the discussions for each module are very informative narratives and data summaries. Additionally, the integration of parameters (i.e., warming trend and fishery exploitation status table mentioned above) may be very useful. This output may be either a very helpful first step as an overview/summary of an LME or may be part of a model into which more modules could be added (i.e., bottom sediment, more on endangered species, shipping, etc.).

The output does not include any cumulative analyses, framework/flowchart/guidance for decision making, but rather a presentation of very useful pieces of the puzzle with which the analyst could produce cumulative analyses using another model.

Eleven distinct LME areas within the United States, including Alaska, Hawaii, and the Caribbean, have been described as shown in Table B-2.

Table B-2: Combined BOEM OCS Planning Areas within LME Boundaries

LME (Name and Assigned Number)	Corresponding BOEM OCS Planning Areas
East Bering Sea (1)	Norton Basin, St. Matthew-Hall, Navarin Basin, Aleutian Basin, Bowers Basin, Aleutian Arc, and St. George Basin
Gulf of Alaska (2)	North Aleutian Basin, Shumagin, Kodiak, Gulf of Alaska, and Cook Inlet
California Current (3)	Washington/Oregon, Northern California, Central California, and Southern California
Gulf of Mexico (5)	Western Gulf of Mexico, Central Gulf of Mexico, Eastern Gulf of Mexico
Southeast US Continental Shelf (6)	Mid-Atlantic, South Atlantic, and Straits of Florida
Northeast US Continental Shelf (7)	North Atlantic and northern section of Mid-Atlantic (from North Carolina to New Jersey)
Insular Pacific- Hawaiian (10)	No OCS planning areas for Hawaii
Caribbean Sea (12)	No OCS planning areas for Puerto Rico
Chukchi Sea (54)	Chukchi Sea and Hope Basin
West Bering Sea (53)	Various
Beaufort Sea (55)	Beaufort Sea

Input data are needed for the five indicators listed above. Additional information would be needed for a thorough ecosystem sensitivity analysis. Although some of these parameters are mentioned in the briefs, the coverage would not be adequate for the scope of an environmental sensitivity analysis. Some data gaps include: sea bottom substrate, marine mammals and sea turtles, impact data including acoustics and sound from ships, project operation, ship traffic, biodiversity indices, coral reef and sea grass, and electromagnetic fields, among others. Information for some parts of Alaska is missing due to lack of data. In other words, the analyst needs to have a prior knowledge of all the potential inputs and impacts to supplement this report to complete a thorough environmental sensitivity analysis. The model does not produce a sensitivity assessment per se. Cumulative impacts are not part of this model as it currently exists; however, there are references to cumulative assessments in the United Nations Environment Programme LME report (Sherman and Hempel 2009).

Although the LME model may be an excellent source for information about productivity, fish and fisheries, pollution and ecosystem health, socioeconomics and governance, it does not provide a cumulative analysis of all impacts together. Additionally, the model is lacking in discussions and analyses on many fine-scale parameters, including bottom sediment, marine mammals and sea turtles distribution and habitat use, Essential Fish Habitat (EFH), shipping traffic impacts, acoustics, electromagnetic fields, as well as specific impacts from each project type.

B.5 ECOLOGICAL VALUE MAPPING

B.5.1 Derous et al. Biological Valuation Map Approach

Ecological value mapping attempts to define ecological value, without reference to human interests, using a spatially gridded approach. By assessing ecological value in a spatially explicit manner, decision makers will be able to make informed choices about development and conservation placement (siting). This method seeks to develop a reliable, meaningful, integrated approach to biological valuation in order to advise management strategies for sustainable use and conservation. Specifically, this method ranks areas according to their inherent biological and ecological value. Two main criteria are used in the assessment of ecological value: (1) rarity (degree to which an area is characterized by unique, rare, or distinct features) and (2) aggregation/fitness consequences (degree to which an area is where most individuals of a species are aggregated and the degree to which the site makes a vital contribution to fitness) (Derous et al. 2007c). Two second-tier criteria are used to further assess biological value: (1) naturalness (the degree to which an area is pristine and characterized by native species) and (2) proportional importance (the proportion of the national, regional, and/or global resource of a species or feature that occurs within a subzone of the study area). These criteria were selected through a rigorously conducted literature search and based primarily on criteria outlined in Section 1.1.2) of the Canadian DFO report "Identification of Ecologically and Biologically Significant Areas."

The general protocol for developing the biological valuation for this method is as follows:

1. Subdivide study area using an ecologically and physically meaningful and practical scale, as well as a practical scale.
2. Collect all available biological and ecological data of the study area and assign to respective subzones (point data, aggregated data, interpolated data).
3. Evaluate biodiversity, which itself is not a valuation criterion; rather, all other selected valuation criteria (rarity, aggregation/fitness consequences, naturalness and proportional importance) are assessed on all levels of biodiversity. By asking a set of assessment questions of collected biological data related to different structures and processes of biodiversity coupled to the proposed valuation criteria, a comprehensive valuation assessment protocol has been established. Detailed questions about structures and

processes of biodiversity can lead to a more objective valuation, because experts could otherwise score a criterion from their own individual perspectives and comparison among valuations would be difficult. (Examples of criteria questions that are assigned scores include: Rarity—Are habitats formed by keystone species present in the subzone? And Aggregation—Is a high percentage of a species population located within the subzone?)

4. Design the valuation protocol. Various algorithms are produced that apply the assessment questions to data of different ecosystem components. Several facets of this involve the interpolation of data for the spatial aspect of this method. This step involves the adaptation of assessment questions to numerical (often 1 through 5) values for criteria. The exact design of the protocol can be adapted to the available biological data.
5. Score the results. Once values have been assigned for each of the assessment questions, evaluate subzones against the chosen criteria requires the application of an overall scoring system. Under this version of the Ecological Value Map (EVM) method, researchers added the scores of the first order criteria together (rarity, aggregation/fitness consequence), thus conferring them equal weighting. Subzone scores were then modified according to the second order criteria (naturalness, proportional importance). The criteria scores are also separated for different ecosystem components so there are different scores for each criterion and subzone according to the type of data (seabirds, macrobenthos, etc.).
6. Assess reliability and revision. The reliability of the assessed intrinsic value should be noted, for instance by attaching a label displaying the amount and quality of the data used to assess the criteria in a certain subzone.
7. Present biological values of subzones. Map the aggregated biological valuation criteria scores for each subzone.

Steps three (creation of criteria assessment questions), four (algorithms for computing criteria assessment question scores), and five (scoring system for amalgamating criteria assessment scores into an overall score) are the most critical and novel aspects of this method.

Rarity is assessed by answering each criteria question using quantitative methods addressing individual species and habitats presence within a study area (nationally rare species are species occurring in less than 0.5 percent of the 10 km×10 km squares within the study area, worth x points. Regionally rare species are worth x – 1 point, etc.). Aggregation/fitness consequence criteria are assessed in a similar fashion. To answer these assessment questions, ecological data within the study area are collected. The data are first collected at a taxonomical group level (individual species, genera, etc.) and then summarized into a broader functional group level (seabirds, marine mammals, demersal fish, etc.) to fit the needs of the valuation protocol. Each assessment question is then answered for each functional group in each subzone (grid). The answer to each assessment question yields a rank/index score. An appropriate scoring system to integrate the scores of the different assessment questions for each grid cell is set up. Scores are amalgamated and plotted in a visual format (value map).

Spatially explicit rarity and aggregation data is required for each taxonomic group of interest in order to thoroughly answer each of the criteria assessment questions. General quantitative data (e.g., >250,000 and <500,000 of species x) is required for each taxonomic group in each grid cell in order to properly answer criteria assessment questions and to subsequently apply valuation criteria scoring. Functional groups that have been assessed in this method include seabirds, marine mammals, macrobenthos, epibenthos, and demersal fish.

Large national databases are required to consistently apply data across a scale as large as OCS planning areas. Smaller datasets may be used to fill in taxonomically specific data, but this results in different inputs for each study area, potentially affecting overall reliability of the method. When data are not all available to properly assess a specific valuation assessment question, it can be skipped, and the lack of certainty in that data will be reflected in the final valuation mapping output. In terms of the OCS planning areas, some data-poor regions would be difficult to properly map. One possibility would be to reduce taxonomic groups of interest to representative groups for which more data exist. Large grid sizes (such as 4 per OCS planning area) would be required for any degree of reliability in planning areas. All functional examples of this method use relatively small subzone grid sizes compared with potential subzone sizes for the BOEM OCS planning areas.

B.5.2 Irish Sea Pilot Approach

The Irish Sea Pilot was set up by the United Kingdom government and the Joint Nature Conservation Committee to develop a strategy for marine nature conservation to be applied to marine waters (Vincent et al. 2004). The scale and focus of the overall Irish Sea Pilot project is outside of the scope of BOEM OCS ESA interest; however, a few facets of the project are relevant.

The process of calculating environmental sensitivity of an area using the Irish Sea Pilot method involves:

1. Mapping habitat extents in study area;
2. Identifying fauna associated with each habitat;
3. Assessing sensitivity of each habitat/biota complex to individual stressors; and
4. Mapping resultant sensitivities (point data).

The project mapped marine landscapes (effectively groupings of spatially related habitats, e.g., photic rock zones, deep-water mud basins, fine sediment plains, etc.), identified constituent biological communities within that marine landscape (fine sediment plains – *Abra alba, Nucula nitida* and *Corbula gibba*; fine sediment plain – *Macoma balthica* and *Abra alba,* etc.), and assessed their sensitivity to a range of human activities respectively. The assessment outlined by this method only dealt with benthic faunal communities in relation to marine landscapes.

An assumption is made in this method that the sensitivity of a community within a habitat is dependent upon and, therefore, is indicated by the sensitivity of the species within that community. The species that indicate the sensitivity of a habitat are identified as those species that significantly influence the ecology of that component community (an *a priori* list of said species is compiled). The loss of one or more of these species would result in changes in the population(s) of associated species and their interactions. The criteria used to identify species that indicate habitat sensitivity subdivide species into 'key' and 'important' based on the likely magnitude of the resultant change. A standard set of definitions and scales regarding the assessment of intolerance, recoverability, and sensitivity are defined. Each marine landscape/ habitat/stressor combination was ranked (very low to very high) on two criteria; intolerance and recoverability (Table B-3). Rankings are based on a flow chart method defined under the MarLIN Flow Chart/Decision Tree section of this report. Intolerance and recoverability are combined using a defined rationale to give an overall sensitivity rank that represents a species' or habitat's susceptibility to damage and the time taken for its subsequent recovery. Strength of evidence for each relationship is also assessed in an index format.

Table B-3: Summary of Representative Component Biotope

Biotope Code	Biotope name	Intolerance	Recoverability	Sensitivity	Evidence
CMS.AbrNucCor	*Abra alba, Nucula nitida* and *Corbula gibba* in circalittoral muddy sand or slightly mixed sediment	Low	Immediate	Not sensitive	High
CMS.AfilEcor	*Amphiura filiformis* and *Echinocardium cordatum* in circalittoral clean or slightly muddy sand	Low	Immediate	Not sensitive	High
CMS.VirOph	*Virgularia mirabilis* and *Ophiura* spp. on circalittoral sandy or shelly mud	Low	Very high	Very low	Moderate
IGS.FabMag	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand	Low	Very high	Very Low	Low

Source: Vincent et al. (2004)

The assignment of sensitivity assessment scores involves the review of available literature on the life history characteristics, distribution, environmental preferences, and any effects of environmental perturbation on the chosen species (somewhat subjective methodology). In the case of habitats, information on the community ecology and structure of the habitat (or similar community) and its associated species is collated. These sensitivities are then amalgamated and maps of sensitivity are produced.

Essentially this method requires the identification and spatially explicit mapping of all habitats through the entirety of a study area. Faunal relationships to habitats must be determined and a finite set of faunal/habitat communities must be defined. The sensitivities of each faunal/habitat community to each individual stressor of interest must be determined. These steps are primarily determined through literature review and expert opinion. For the example method, all the survey data available, for both habitats and species, was point data. No information on the spatial extent of habitats was available, undoubtedly resulting in somewhat confounding results of the mapping portion of the method. Similarly, where habitat complex data existed, the data was point data only. Survey data could only be tagged with sensitivity information for the species and biotopes so far researched within the MarLIN program.

The output of the Irish Sea Pilot sensitivity analysis is a table and sensitivity map relating habitat community sensitivity to individual stressors. The sensitivity map highlights areas which are particularly sensitive to stressors. Each sensitivity map represents locations of habitats; habitats are represented as polygons (not gridded data).

This method has only been undertaken in the Irish Sea. The Irish Sea area was selected for the Pilot because it was considered to be one of the most ecologically distinct regional seas around the UK. The purpose was the testing of implementation of this method for determining marine areas of national importance to the UK. This method is mainly documented in government documents and reports.

Results of this method produce spatially explicit sensitivity assessments useful for siting exercises. This aspect of the method is not particularly applicable to the BOEM OCS project. Sensitivities could potentially be summarized over an entire OCS planning area to produce a ranking or score as opposed to an aggregated mapping. Cumulative impacts are difficult to work into this method. Because each habitat/biota/sensitivity is individually determined and mapped, each combination of cumulative impacts would also need to be assessed, producing an endlessly large matrix of relationships. Climate change would need to be added as its own set of stressors to the habitat/species/stressor matrix. This method includes “recoverability” as an input for overall sensitivity, a near proxy for resilience.

The Irish Sea Pilot sensitivity mapping method requires the calculation (ranking/indexing) of species/habitat/stressor relationships. Then, using point data available on locations of species/habitat complexes, sensitivity maps are produced. The method, even if modified to apply to more broad-scale habitat complexes, essentially adds another layer of complexity to an already complex problem (environmental sensitivity). By attempting to first define a habitat/species relationship, then categorize each of these relationships, and only then assess sensitivities of each of these relationships adds undue difficulties and room for error/subjective reporting. The final output of sensitivities is even more spatially explicit than the Derous et al. 2007a, b, and c (spatially gridded) methodology.

B.6 VULNERABLE MARINE AREAS APPROACH

This method, based on Zacharias and Gregr (2005), relies on an environmental sensitivity assessment of *a priori* identified valued ecological features (VEFs); biological or physical features, processes or structures deemed by humans to have environmental, social, cultural, or economic significance (estuaries, sand flats, sponge reefs, etc.). Vulnerable marine areas (VMAs) are defined by evaluating VEFs in terms of their sensitivity and vulnerability to particular stressors. This concept is easily applied to spatial mapping as the distribution of both the VEFs and stressors can be mapped, allowing for visual inspection of their overlap, and therefore interaction potential.

The three main components of this method are:

1. Identification and mapping of valued ecological features;
2. Identification of valued ecological feature sensitivities and vulnerabilities; and
3. Prediction of VMAs with ecological classifications.

For the first step (identification and mapping of VEFs), VEFs may be species, habitats, communities, or processes that contribute to the formation and maintenance of populations, habitats, or communities. There is no predefined appropriate scale for VEFs and can therefore be identified on a project by project basis. VEFs must be able to be spatially delineated and mapped. This may be as simple as outlining the extent of a particular habitat of interest, or as complex as the spatiotemporal study of a marine mammal/habitat relationship.

For the second step (identification of VEF sensitivities and vulnerabilities), a matrix is developed listing VEFs of interest and the potential stressors associated with each stress class (Table B-4).

This will identify the subset of stressors specific to the VEF; if a VEF and stressor will never interact in the environment, there is no need to assess potential sensitivity. A key aspect of assessing sensitivity is the selection of appropriate indicators that must be sensitive to the stressor being considered (this method does not provide a list of indicators).

Table B-4: Examples of Valued Ecological Features Identified in Eastern North Pacific and Their Potential Stress Classes

	Chemical contamination				*Biological contamination*				*Nutrient loading*			*Sedimentation and organic loading*					*Physical disturbance*									*Community disturbance*								
Valued Ecological Features	*chemical spills*	*oil spills*	*non-point source, marine*	*sewage/outflow*	*sediment mobilization*	*bacterial and viral*	*species introductions, macro*	*species introductions, micro*	*agricultural runoff*	*urban runoff, processed*	*urban runoff, unprocessed*	*upstream/upland development*	*land-cover alteration*	*dredging*	*log handling and storate*	*industrial processing*	*breakwaters*	*groins*	*dykes*	*dumping*	*dams*	*reclamation*	*research activities*	*dredging and infilling*	*marine platforms*	*change in freshwater input*	*thermal pollution*	*bottom trawl*	*direct mortality*	*indirect mortality*	*prey removal*	*vessel strikes*	*noise pollution*	*vessel congestion*
Community types																																		
estuaries	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X					X		X	X							
salt marshes	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X					X		X								
seagrass beds	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																	
kelp beds							X		X	X					X											X	X		X					
tidal flats	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X					X		X	X							

Source: reproduced from Zacharias and Gregr (2005)

The analysis of a VEF/stressor relationship produces a sensitivity surface representing sensitivity as a spatially distributed probability. Each gridded cell represents the probability of VEF/stressor overlap. Identification of VEF-stressor overlap requires extensive spatial aggregation data, as well as ecological data on effects of stressor on that particular VEF.

The third step (prediction of VMAs) is not well defined and is minimally discussed in the article outlining this method. The output is a gridded map of probability of VEF-stressor overlap. Data values for overlap probability, which determine grid value.

The published example examines marine mammal relationships with acoustic stress along the Pacific coast of Canada. No other uses of this method could be located in peer reviewed literature.

This method is a direct environmental sensitivity assessment. However, it provides individual component/stressor sensitivities, not a cumulative sensitivity analysis for a study area. Results are spatially explicit and no method is outlined to summarize multiple stressor sensitivities over a larger study area. Methods could be developed to create cumulative stress maps (additive, as per Derous et al. 2007c) as well as cumulative impacts and climate change (perhaps multiplicative). However, no methods touching upon these subjects are proposed in this article.

The Valued Ecological Component method seeks to define individual ecological component/stressor relationships allowing for more detailed analysis. It provides no method for analyzing overall sensitivity of a study area. The spatial mapping components of this method are beyond the scope of the OCS project. The ultimate goal of this method, identification of vulnerable marine areas for conservation purposes, is also outside of the scope of the BOEM OCS project. This method provides no method for combining individual stressor/indicator relationships into summarized scores/ranks for an area. Concentrating only on "valuable" ecological components (though this concept could easily be changed) is not in line with assessing overall environmental sensitivity. *A priori identification of indicators of concern is an interesting concept contributing to objective assessments, which should be kept under consideration for the BOEM OCS project as a whole*. Overall the methods discussed here are more thoroughly discussed in the prior ecological mapping approaches.

B.7 FLOW CHART/DECISION TREE

B.7.1 MarLIN Environmental Sensitivity Approach

The Marine Life Information Network (MarLIN) is an initiative of the non-profit organization Marine Biological Association of the UK. The mission of MarLIN is to "provide information and resources to support marine environmental management, conservation and education." To this end, MarLIN has developed a method for assessing environmental sensitivity and recoverability of marine species and habitats (Tyler-Walters and Jackson 1999). Various reports on this method provide guidance for data researchers on the application of the proposed rationale and are intended to ensure that sensitivity assessments that utilize this method are made in a consistent and systematic manner. The "user guide" report is designed to provide potential users of the method with a clear understanding of how sensitivity and recoverability assessments are made, their inherent assumptions or limitations and, therefore, applicability to environmental protection and management. The method uses several score indexing methods and provides an overall assessment rather than a score. The author's avoid the term "score" because they feel it implies quantitative values, while the assessments provided by the methodology are qualitative in nature.

The assessment process involves judging the sensitivity of a species or habitat to change in an environmental factor by an external activity (stressor). The process then assesses the likely recoverability of the species or habitat in cessation of the activity. Basic sensitivity rankings (high, mid, low) are assigned for each species (species group or habitat)/stressor (e.g., dredging, water temp change, noise, etc.) relationship utilizing a matrix method. Decision flow charts are used to assign these rankings. Each relationship is then refereed by peer review. Though no methodology for producing individual sensitivity scores for a study area is outlined in this method, species and biotope assessments can theoretically be combined to create overall sensitivities for each area of study.

The procedure used to assess species sensitivity involved the following stages:

1. Review relevant available information for the species in question;
2. Assess the quality of the data used;
3. Identify the likely sensitivity of the species to external factors;
4. Identify the likely recoverability;
5. Submit resultant key information review to referees; and
6. Modify conclusions to take account of referees comments.

As information is collated, data fields in the MarLIN database are completed.

Step 3, identification of the likely sensitivity of the species to external factors, is based on a flow chart methodology. The information compiled in the species database (steps 1 and 2) is used to objectively (or at least as objectively as possible) move through each flow chart.

Step 4, identification of species recoverability, is determined using a similar (but recovery/resilience-oriented) flow chart method. Although each flow chart is set up to be binary (yes/no) in nature, some answers are innately subjective due to the questions provided (e.g., Recruitment: Do the larvae or juveniles have a high dispersal potential?). To address this issue, this method has set standard 'benchmarks' to enable the assessment of sensitivity relative to a specified change in an environmental factor (for the above flow chart the benchmark of disturbance is “All of substratum occupied by the species or biotope under consideration is removed. A single event is assumed for sensitivity assessment. Once the activity or event has stopped suitable substratum remains or is deposited. Species or community recovery assumes that the substratum within the habitat preferences of the original species or community is present.”). This was accomplished through an *a priori* identification of environmental factors likely to be affected by maritime activities and natural events. Information related to benchmarks is also run through a flow chart.

The data inputs of this method are derived directly from a database that includes each species’ key information (taxonomy, general biology, habitat preference, reproduction, sensitivity, resilience, endangered species status). MarLIN has been continually updating their databases for the past 12+ years. Additionally, a database for habitats is required (basic information, biotope classification, ecology, ecological relationships, seasonal and longer term changes, additional ecology, habitat complexity, productivity, recruitment processes, time for community to reach maturity, habitat preferences and distribution, species composition, sensitivity and recoverability, marine natural heritage importance). The overall method requires the completion of this database for all species within the study area (though they concentrated only on seabed species, allowing this task to be much smaller in scope than would be for the BOEM OCS method).

A sensitivity index ranking is assigned for each species and habitat within the study area. No direct methodology is defined for aggregating these scores into a summary for an entire study area. Having baseline sensitivities for each species would allow for potential methodologies of weighting each species by abundance, rarity, etc. in order to get a more direct ranking for an overall study area. The authors suggest that the next steps in development of this method should include utilization of GIS mapping to best display and summarize sensitivity data. This would further increase the data demands (direct knowledge of both species and habitat locations in each study area would be required) and time investment to complete this method.

This method has been carried out in waters surrounding the United Kingdom including the Irish Sea. No examples have been located of this method being utilized outside of the development group or in study areas outside of the United Kingdom.

This method directly assesses the sensitivity of marine species and habitats. This method also directly assesses the recoverability (easily adapted to the definition of resilience for this study). These aspects of the methodology alone are of interest to this project. Unfortunately, no method is defined for incorporating the various species/habitat scores into a cumulative sensitivity or resilience score for an area. However, these base data could be combined with another methodology to achieve a summarized ranking. This method does not consider cumulative impacts and does not have a method for assessing them. Climate change has not been a consideration of this method yet, but could be incorporated as further physical and/or biological factors of disturbance.

The Marine Life Information Network (MarLIN) method provides a novel approach to the characterization of sensitivity and resilience of marine species and habitats. The assessment process involves using information from current scientific literature to identify the likely intolerance of a species to change in an environmental factor arising from human activities or natural events. The rationale then assesses the likely recoverability of the species following cessation of the human activity or natural event. Intolerance and recoverability are then combined to provide a meaningful assessment of their overall sensitivity to environmental change. Assessment of intolerance requires a specified level of environmental perturbation. Therefore, the MarLIN program has developed a set of 'benchmark' levels of environmental change in the environmental factors against which to assess sensitivity. The benchmarks also allow intolerance and hence sensitivity to be compared against the predicted effects of planned projects or proposals. The assessment of intolerance and recoverability is accomplished through *a priori* defined binary decision trees. The design of these decision trees is such that some answers will be innately subjective in nature. Adapting the decision tree questions to be more objective (essentially more quantitative) in nature would be critical to allow this methodology to stand up to more extensive peer and legal review. Despite the lack of a method for amalgamating sensitivity rankings in a meaningful way, this method is critical to consider when designing sensitivity analysis for the BOEM OCS planning areas. The effective design of a flow chart methodology could potentially be a useful method to assigning sensitivity indexes/rankings.

B.7.2 Massachusetts Ocean Management Plan Ecological Valuation Index

The Massachusetts Ocean Management Plan developed the Ecological Valuation Index for Massachusetts state waters (Executive Office of Energy and Environmental Affairs 2009). This method does not directly assess environmental sensitivity. The purpose of the Ecological Valuation Index is to categorize the intrinsic ecological value of subareas within the Massachusetts planning area using selected ecological criteria, thus permitting comparison of these subareas. In particular, development of the Ecological Valuation Index allows for the combination of spatial data representing individual components of the ocean ecosystem—species and habitats—thereby moving towards consideration of the ecosystem as a whole. Ecological value scores are assigned for each species and habitat of interest using criteria questions, and then the partial extent of each species is mapped to produce summed ecological values by area grids. The Ecological Valuation Index is defined as the "numerical representation of the intrinsic ecological value of a particular area, excluding social and economic interests." The steps involved in this method are straightforward and derivative of the Derous et al. (2007c) and Canadian DFO ecological valuation mapping methodology:

1. Delineation of the planning areas;
2. Data collection and selection process;
3. Selection of ecological valuation criteria;

4. Development of assessment questions;
5. Scoring; and
6. Generation of Ecological Valuation Index for each species and final Ecological Valuation Index for each location.

This method employs spatial analysis techniques wherein ecological data are gridded and mapped. Spatial interpolation was used to fill gaps where data did not exist, resulting in representative surfaces for each ecological component (indicator). Ecological data assessed included presence/absence of species, habitat areas, critical habitats, seafloor characteristics, and fisheries. In this method, spatial ecological data are evaluated under four criteria adapted from Derous et al. 2007c: (1) major contribution to fitness, (2) spatial rarity, (3) population of global importance, and (4) population of regional importance. A set of assessment questions is developed under each of these criteria (i.e., major contribution to fitness: Does this area make a major contribution to the survival and/or reproduction of the species or population?) as per the Derous et al. (2007a, b, and c) methodologies. However, in this method a simple binary scoring technique (yes/no) was applied to the data for each of the four criteria (Table B-5). Once data layers are compiled, scores are calculated (using various algorithms) in each grid cell to calculate an overall mapped spatial index.

Table B-5: Whale Species, Ranks for Criteria Supporting Ecological

Species	Scientific Name	Major Contribution to Fitness	Spatial Rarity (<10%)	Population of Global Importance	Population of Regional Importance	Ecological Valuation Index
Fin Whale	*Balaenoptera physalus*	0	0	0	1	1
Humpback Whale	*Megaptera novaeangliae*	1	1	0	1	3
North Atlantic Right Whale	*Eubaleana glacialis*	1	0	1	1	3

Data requirements for this method are comparatively minimal. Even so, extensive data research is required (particularly for spatial aspects). For this method, researchers focused on habitat and fisheries data (though other functional groups could ostensibly be added). Spatially explicit data must be collected throughout the study area in order to support the overall mapping aspect of this method. Several work groups were formed to support the Plan. A Habitat Work Group approached the process of defining habitats from three different angles to determine the overall and relative "importance" of particular species or habitats. Three main tracks were used to address their task: existing legal protection, biotic criteria, and abiotic criteria. A Fisheries Work Group was tasked to identify locations in the planning area important to fisheries. This work group developed two main summary map products: (1) a map indicating areas of relative importance to fisheries resources, and (2) a map indicating areas of relative importance to commercial fisheries. Data from these workgroups are utilized to assess ecological values using the flow chart method.

The result was a spatially explicit ecological value map that represents the summed value of index scores for ecological components of interest. The data that feed this map are a set of matrices of each ecological component and its index scores (0 or 1) for various criteria that were assigned via assessment questions (flow chart).

This method was custom designed to be used in state waters of Massachusetts. It was a statewide effort to assign ecological value to spatially explicit regions of the State's marine waters. This method has not been used in other regions.

Portions of this method are more suitable than others for this to be worked into the BOEM OCS study. The spatially explicit mapping of species' spatiotemporal locations is potentially useful for OCS planning. The methods of assigning value and then summarizing these criteria for each individual species/habitat are much more applicable. The creation of *a priori* questions to assign value for each criterion is potentially useful. The binary nature of indexing seems both beneficial and detrimental to the larger project. By having every question answered yes/no, answers become much more objective (so long as the questions and criteria themselves are objective). However, this binary scoring removes much of the precision gained from finer resolution assessment of species and habitats. The scoring component theoretically allows for cumulative impacts to be assessed through additive or multiplicative procedures. Climate change was not considered in this method and would need to be added as an addition to the list of potential stressors. Resilience is not a component of this method.

The Massachusetts Ocean Management Plan ecological value index method does not provide a scientifically rigorous evaluation of environmental sensitivity. By simplifying each ecological criterion to a binary form, much precision is lost. The criteria valuation methodology of scoring each individual species is of interest to the project as a whole.

B.8 ECOLOGICAL QUALITY RATIOS – EUROPEAN MARINE STRATEGY FRAMEWORK DIRECTIVE

The Marine Strategy Framework Directive (MSFD) is a framework adopted by the European Union to help Europe achieve "Good Environmental Status" in their seas. To achieve this, the Directive requires the assessment of the current state of seas. The MSFD is modular in concept with a set of 11 qualitative descriptors (broad ecological concepts such as biological diversity, invasive species, food webs, pollution, etc.) that together summarize the way the whole ecosystem functions. The European Commission has subsequently proposed an extensive set of indicators (more specific potentially qualitative measures such as distributional range of a species, fishing mortality, distribution of noise pollution, etc.) to assess environmental status of each individual descriptor. Certain descriptors included in the MSFD are pertinent to the BOEM OCS effort (biodiversity, seafloor integrity) while others (seafood contamination, eutrophication) have a much more limited connection.

This method presented by Borja et al. (2011) outlines a methodology for working within the Framework Directive to effectively assess environmental status. Assessments are conducted for each descriptor and an Ecological Quality Ratio (EQR) is derived for a study area for that descriptor. EQRs range from 0 (low value) to 1 (high value). The basis of EQRs is the comparison of a study area's current environmental status with respect to reference conditions. Though this method is well documented in peer reviewed journals, other environmental status studies contest that attempting to classify reference conditions is both difficult and may be fundamentally flawed. Likewise, converting this type of assessment to the current environmental sensitivity assessment score would be difficult.

The process of calculating EQRs for each indicator and descriptor is extremely data intensive (species-specific information). Calculation of each EQR utilizes various algorithms (outlined in cited articles and reports). Methods for assessing the descriptor "biological diversity" (which may most strongly relate to environmental sensitivity) range from combining various biota specific indices (Borja et al. 2009a) to using the ecological value mapping methodology of Derous et al. (2007c). Each of the methods presented in this method for assessing EQRs of each indicator/descriptor are derived from peer reviewed journal articles.

Multiple methods are suggested for integrating EQR scores into a meaningful overall status for a given study area. In Borja et al. (2004), component scores are incorporated into a decision flow chart to assess environmental status. Under this method, the classification of the ecological status is based upon the worst of the values in the biological elements. Hence, if the fish indicator has a poor value, while the remainder of the elements has a good status, the overall area classification should be poor ecological status.

The most recent, and most pertinent method for score amalgamation suggested under the umbrella of this method is presented in Borja et al. 2011. Under this method, a table calculation is performed to assess overall status. Each descriptor shows the associated indicators used to assess the status in the studied area, together with an explanation of the criteria adopted for the assessment. A Delphic process is used to weight each descriptor (numerous publications outline this weighting method). Using this process, descriptors of more concern (i.e., biodiversity) can be weighted appropriately as per the researcher's needs. Reliability of data and methodology for each assessment is also considered adding a further weighting value to each descriptor.

In summary, an EQR is calculated for each indicator. An EQR is calculated for each descriptor as the average value of its indicator's EQRs. EQRs for each descriptor are integrated using various weighting and averaging algorithms to create an overall status score for a study area. This final score, under this method, is an environmental status ranking (low through high), not an environmental sensitivity ranking.

Large amounts of quantitative assemblage data are required to assess each biological component (particularly if utilizing the Derous et al. (2007c) method to assess biological diversity). Each biological component's needs are unique to the assessment used, but data input needs should be considered generally analogous to ecological value mapping/indexing methods. Potentially smaller amounts of data are needed that are spatially explicit in mapping methods.

Ecological quality ratios are calculated for each descriptor. EQRs, which range between 0 (bad) and 1 (high), are then divided then into five quality status levels (high, good, poor, and bad status), depending on the distance to reference conditions (Borja et al. 2004; Borja 2009b). Decision flow charts are then used to integrate EQRs from each component to assign an overall ecological status (high to low) to a study area. Alternatively, EQRs are calculated for each descriptor and combined in a tabular format to give an overall environmental status score per study area.

This method does not directly assess environmental sensitivity. At its core, this method assesses current environmental status compared with a reference environmental status. This method addresses cumulative impacts in their present effect on a study area, but does not address potential sensitivity to future cumulative effects. Climate change is not addressed in this method, and would need to be incorporated into each of the descriptors, as opposed to being added as its own descriptor (speculatively). Resilience is not an implicit part of this method, though may be incorporated into several indicators. The comprehensive nature of this method is well suited to the needs of this project, but does not address individual impact sensitivity.

At its base, the MSFD does not directly address environmental sensitivity. However, the modular methodology outlined for combining various descriptors into a final environmental status score is very similar to the current BOEM ESA method. The methods suggested by Borja et al. 2011 utilize methodologies of environmental sensitivity (or like concepts) provided by numerous earlier studies that directly address individual components (e.g., macrobenthos, demersal fish, etc.) as opposed to developing methods for assessing each component within the larger method. Then, each individual component can be worked into the larger framework. Using this technique ostensibly allows this method to use better-developed methods of assessing individual components (descriptors) while still achieving an overall area score. Then, well-developed algorithms and weighting schemes are used to unify these different scores into usable and comparable EQRs. This method directly addresses many of the needs of the BOEM OCS project including accounting for reliability of results and weighting of components based on *a priori* decisions. The tabular integration of EQR scores presented in Borja et al. (2011) should be strongly considered as a basis for future large scale environmental sensitivity methods, though significant changes will be needed to adapt it to a definition of environmental sensitivity as opposed to environmental status.

B.9 RELATIVE RISK MODEL

The Relative Risk Model was developed to address a perceived issue of ecological risk assessments being too narrowly focused on site-specific or individual stressor components. This model is in general a more terrestrial-based method than other methods outlined in this report, concentrating on coastal habitats. However, overall concepts presented by this method are extendable to marine habitats (as seen in Fock 2011). The Relative Risk Model is designed to rank and sum individual risks numerically within each subarea (of a larger study area), from each stressor source to each species/habitat of interest. The goal of the Relative Risk Model is to help in decision making and planning in varied ecosystems. The application of Relative Risk Models has been useful in typical regional ecological risk assessment scenarios, making it a method of particular interest to the BOEM OCS project. Regional risk assessments attempt to combine multiple species/habitats, stressors, and impacts to create a variety of assessment endpoints. This method focuses on the degree of overlap among potential stressors and species/habitats, and potential impacts of each stressor on each species/habitat. Data availability for larger regions as well as for a wide range of stressors is almost always uneven. Interactions and indirect effects among the organisms within the receiving habitat are frequently not well understood. Keeping these limitations in mind, the Relative Risk Model generates relative risk rankings, testable hypotheses about risk, and pathways for future concern while working within spotty data environments. To this end, the Relative Risk Model operates as a decision-making tool for risk managers.

The application of a Relative Risk Model involves dividing the study area into subareas each containing specific ecological and anthropogenic structures and activities. Within each subarea, the stressor sources are analyzed to estimate exposure of receptors within habitats leading to effects (impacts) relevant to the chosen assessment endpoints. The subareas are analyzed and compared to form a region-wide perspective of ecological risk. Utilization of this method in the past has concentrated on developing relative risk rankings for chemical and physical stressors from various sources.

Ranks are assigned to each source and habitat type on a 2-point scale from 0 to 6, where 0 indicates lowest potential for exposure and 6 the highest. Filters are used to determine the relationship between risk components (sources, habitats, and impacts to assessment endpoints). A filter consists of weighting factors 0 or 1 indicating low or high probability, respectively. Two filter types exist: *exposure* and *effect*. The exposure filter screens the source and habitat combinations likely to result in exposures. The effect filter weights those likely to affect a specific assessment endpoint. To integrate factors affecting risks in a study area, the ordinal data is converted in the form of ranks into a point system that is then combined mathematically.

Integration occurs in two steps. The first involves integrating the source and habitat ranks by multiplication. This allows the effective demonstration of a source in a high-ranking habitat as more important than the same source in a low ranking habitat. The filters refine the resulting values to account for the likelihood of an exposure or effect occurring with each particular combination of source and habitat. The second integrative step is to add all the points received for a particular component of the study area (subarea, source, or habitat) and to compare the final tally. The results represent a set of points of comparative value.

One of the keys to the utility of the Relative Risk Model is the detailed listing of explicit assumptions and ranking criteria. The detailed accounting of the rankings and the exposure and effects filters makes careful examination of risk factors straightforward. As data become available, changing ranking factors and recalculating the resulting ranks is relatively easy.

A ranking method can combine risks from many sources to a variety of assessment endpoints, but it does not provide an estimate of absolute risk. Another limitation of the method is that relative ranks between regions cannot be compared in the same manner as absolute numbers. Risk levels among regions, for example the northern GOM and the Chukchi Sea, cannot be directly compared unless if the process incorporates both study areas with common criteria for ranking sources, habitats, and filters. A critical caveat in the interpretation of the ranks and scores from a ranking risk assessment method is the tendency to emphasize numerical score or ranking without careful consideration of data used to feed the model. These scores collapse a multivariate construct into just one variable, hiding a great deal of information critical to the decision-making process. Over-reliance on a summary number, the authors note, is not wise.

The Relative Risk Model has been developed in recent years to utilize more of an algorithmic method (Fock 2011), rather than a ranking/scoring approach described above. As opposed to constructing criteria questions with a discrete (potentially *a priori* defined) number of potential answers (scoring/ranking) or using flow charts/decision trees to assign scores/ranks which are used to assess attributes of sensitivity, algorithmic approaches use empirical data to feed equations which assess attributes of sensitivity. The empirical input data is not categorized or grouped in any way. The input data is normalized or modified only as to spatiotemporal concerns among study areas. In this respect, algorithmic version of the Relative Risk Model is more process based than other approaches which use ranking and scoring. It fundamentally differs from the ranking/scoring approaches in that it does not arrive at pre-defined but arbitrary values (ranks) to assess sensitivity or risk.

This method relies on three distinct categories to define relative risk: stressor, habitat and impact. In order to be able to effectively compare risk among OCS planning areas, an *a priori* list of both stressors and habitats would need to be constructed. Then both the potential of overlap among each stressor and habitat needs to be defined within each planning area as well as the impact of each respective habitat/stressor relationship. Ostensibly, a database (similar to the MarLIN database) would need to be constructed containing detailed information on stressor, habitat relationships.

The overall output of the model is relative risk scores that are comparable among sub-areas of the study area. The numerical values presented are only meaningful within the individual study, not across risk assessments conducted with different base data. Prior to this step, numerous tables of risk are compiled. The habitat/stressor database that serves as a basis for assessment is also a quantifiable output of this method.

The initial proof of concept (from which images above are taken) was conducted in coastal environments of Port Valdez, Alaska. The most recent and applicable utilization of this method was conducted in the marine waters of Europe (Fock 2011). The near-shore marine environment around Cherry Point, WA, USA was used in a Relative Risk Assessment model. This adaptation of the method sought to (1) to analyze cumulative impacts from multiple sources of chemical and non-chemical stressors in the near shore region and upland watersheds of Cherry Point (2) to determine the utility of Monte Carlo type uncertainty analysis in a rank-based regional risk assessment and (3) to investigate the effects of model habitat characterization on risk estimates. The Lotic environment of the Lihue River was assessed using this method (Liu et al 2010). Numerous terrestrial examples of this method have been conducted including the Brazilian rain forest (Moares et al. 2002), a Tasmanian watershed (Walker et al. 2001), the Androscoggin River watershed, ME, USA (Landis et al. 2006) and the Codorus Creek Watershed of Pennsylvania, USA (Obery and Landis 2002). A quality overview of uses of this method can be found in the article “Ten Years of the Relative Risk Model and Regional Scale Ecological Risk Assessment” (Landis and Wiegers 2007).

This method is widely used to assess ecological risk in a variety of ecosystems. Cumulative impacts are not directly addressed by this method but may potentially be implemented using various algorithms. Climate change has not been included as a facet of this method, but again could potentially be included as another weighting factor as demonstrated in the current BOEM ESA method. Resilience is not explicitly addressed in this method, though it is accounted for in the degree of the impact assessment of each stressor on each habitat.

Ecological Relative Risk Assessment is a widely used method that summarizes multiple stressors on various habitat features in a variety of ecosystems. It is a well-documented method that can be modified to fit the needs of a particular project. As stated in the method’s initial proof of concept, the Relative Risk Assessment method is robust and has potential for use with multiple stressors and for broad geographic areas. This fact has proven true in the 13 years since its initial use and documentation, with a large range of ecosystems analyzed within the framework of Relative Risk Assessment. The overall scoring/ranking system produced by a Relative Risk Assessment is very similar to that produced by the current BOEM ESA method. Data demands for this method are high due to the quantification of impacts of each stressor on each habitat (and potentially each species of interest*)*. The overall theory of Relative Risk Assessment is well in line with the goals of the BOEM ESA project and should be further investigated as to its direct applicability. The various algorithms and weighting mechanisms used in this method are critical to consider when developing a new environmental sensitivity method.

B.10 ENVIRONMENTAL VULNERABILITY INDEX – ABU DHABI COASTAL ATLAS AND ENVIRONMENTAL VULNERABILITY INDEX APPROACH

Environmental vulnerability indices serve to define the vulnerability of habitats to environmental stressors such as habitat degradation, water quality issues, invasive species, and climate change. Using an index-based approach allows rapid and rigorous characterization of vulnerability. This standardized method can also be easily combined with other indices, such as social and economic vulnerability, in support of broader sustainability type assessments.

Conceptually, the vulnerability of coastal habitats to environmental stressors is considered as a function of the sensitivity of each habitat to a particular stressor and the relative value of that habitat in general. Sensitivity is defined as a function of exposure, effects, and recovery time. Exposure is defined as the likelihood of exposure to a particular stressor and effect is defined as the magnitude of the impacts of that particular stressor on a particular habitat. Habitat recovery is defined as the speed of relative natural recovery following exposure to a particular stressor. Exposure, effects and recovery are all specific to the impact of a particular stressor on a particular habitat. It is important to note that stressors are considered as independent of the activities that generate the stressors (e.g., dredging causes physical habitat loss, turbidity, and sedimentation). Stressors defined for this assessment include:

- Physical habitat loss and degradation
- Oil spills
- Chemical spills
- Metals and trace elements
- Thermal stress
- Salinity stress
- Harmful algal blooms
- Low dissolved oxygen
- Turbidity
- Sedimentation
- Nutrient enrichment

- Sea-level rise
- Invasive species
- Terrigenous-based pollution
- Overexploitation of resources

Each habitat was assigned an integer score ranging from 0 to 4 or 1 to 4, depending on its exposure to a particular stressor, the effect of that stressor, and the length of recovery following exposure (ASA and Research Planning, Inc. 2010b).

Additionally, each habitat was assigned a ranking score based upon its relative ecological value. These scores were assigned considering only the biogenic structure of the habitat (i.e., ecosystem level). Habitat value is defined as the relative value of ecological functions as defined by habitat-specific attributes such as biological and genetic diversity, relative primary and secondary productivity, critical habitat for locally important species, rareness, global relative value, etc. and is not specific to a particular stressor.

Habitat sensitivity and value, as described above, are considered to be the homogenous for all areas, or patches, of each habitat. Location, or patch-specific, habitat value and risk have also been incorporated into this vulnerability index. Sensitivity and patch risk are both stressor specific, but value and patch value are stressor independent.

The values of sensitivity, overall value, patch-specific value, and patch-specific risk can be combined in a number of ways allowing users to calculate Environmental Vulnerability Index (EVI) values on-the-fly depending on the stressor and availability/reliability of local value and risk data. The four possible inputs to the EVI are habitat sensitivity (S), habitat value (V), patch risk (R), and patch value (Pa). The first two inputs will always be used. Given the two optional inputs, four different algorithms are required. The simple case algorithm, with no patch specific risk or value is:

$$EVI= (S * V)/4$$

If patch-specific risk is populated and included, the algorithm is:

$$EVI = (R * S * V)/16$$

If patch-specific value is populated and included, the algorithm is:

$$EVI = (S * (V+Pa/2))/4$$

If both patch-specific risk and value are populated and included, the algorithm is:

$$EVI = (R * S * (V+Pa/2))/16$$

Spatially explicit habitat data are required for calculating habitat vulnerability because:

1. A single habitat type can be considered multiple ways in calculating sensitivity depending on other attributes, such as depth.
2. Habitat values can be location dependent (patch-specific values).
3. The risk of exposure of a particular habitat type can depend on its location relative to stressor triggers.

In the case of the Abu Dhabi EVI, a hierarchical habitat classification called Coastal and Marine Resources and Ecosystem Classification System (CMRECS) was used as input to the sensitivity and value calculations (ASA and Research Planning Inc. 2010a). CMRECS was created by combining several types of remotely sensed imagery data, vector representations of benthic habitats, and nautical charts. It is a hierarchical and flexible system, with two-dimensional space being partitioned into units that can be described at each level of the hierarchy.

The hierarchy contains the following levels:

1. System
2. Subsystem
3. Zone
4. Geoform
5. Hydroform
6. Macrohabitat
7. Habitat

Important levels of the hierarchy for sensitivity calculations include both the macrohabitat and habitat levels, which are classified using fine-scale land-cover defined by geomorphology, substrate, and/or floral or sessile benthic community or species associations. Using the habitat and macrohabitat designations, the CMRECS data were divided into habitat groups based on how those groups of habitats respond to certain stressors and whether sensitivity is dependent on other attributes such as depth.

Outputs from the EVI calculation include an annotated CMRECS dataset, which contains fields for local relative value and local relative risk, a habitats sensitivity table, which contains the relative sensitivity value of each habitat type to each stressor, and a habitats value table which contains the relative value of each habitat type. The annotated CMRECS dataset containing values for local relative value and risk is editable so that users can update patch-specific values as necessary. Outputs also contain sensitivity maps for each stressor, accessible through a publically available website.

The Abu Dhabi EVI was developed to provide a greater understanding of how various environmental stressors affect the local habitats. The primary purpose is two-fold. A public website allows users to quickly analyze the sensitivity of local habitats to various stressors in support of a public education initiative to increase awareness of environmental issues. A desktop application leads policymakers and scientists through on-the-fly vulnerability calculations to support siting and scoping analyses.

This EVI was implemented for the entire EEZ of the Emirate of Abu Dhabi in the United Arab Emirates. The study area included offshore, nearshore, coastal, and a narrow strip of onshore areas.

This method directly assesses environmental sensitivity and provides stressor specific, spatially explicit sensitivity assessments at a very high spatial resolution. The detailed geo-spatial data required to execute this method may appear to preclude its use on a larger spatial scale; however, the algorithms developed for combining relative habitat sensitivity and value with patch-specific habitat value and risk may merit further investigation for suitability to this project. Removal of the patch-specific dependencies, which is documented in the technical discussion of this method, may reduce the data requirements to a level more appropriate to the BOEM OCS project. The geographic reach of the habitat types included in this assessment (from narrow coastal strip to EEZ limits) is similar in nature to the reach of the BOEM OCS project.

While cumulative impacts are not addressed they could be incorporated through combination with other methodologies. Climate change is not directly addressed, but is included as a contributor to several of the stressors including sea level rise and thermal stress and additional stressors could be defined as necessary to strengthen a climate change assessment. While resilience is not directly addressed, habitat recovery is incorporated into the habitat sensitivity calculations and may provide a reasonable proxy.

This method directly addresses environmental sensitivity, and is similar to the NOAA ESI shoreline in that it provides habitat specific sensitivities to specific stressors. A key difference between the NOAA ESI maps and this EVI method is the extension of the sensitivity to offshore marine habitats and the inclusion of many additional stressors. The EVI method also uses a lower precision sensitivity scale (0 to 4 rather than 1 to 10) and a simplified method to determining habitat sensitivity (fewer contributing factors). Sensitivities are provided on spatially explicit, stressor specific basis and no methodology for determining cumulative impacts or aggregating sensitivity over a larger planning area is provided. This method is may be too data intensive for application to the BOEM OCS project as implemented, but there is potential for leveraging parts of the methodology including the algorithms used to determine vulnerability depending on availability of overall sensitivity, overall value, patch-specific value, and patch-specific risk depending on the variability of data availability for the BOEM OCS analysis areas. The incorporation of recovery (as a proxy for resilience) may also be worth further exploration.

B.11 METHOD EVALUATION

In order to select recommended options for the analysis, the Study Team reviewed how well each method met the evaluation criteria (Table B-7). This process helped systematize the method evaluation. The selection process was then simplified by qualitatively grouping similar methods into basic categories as shown in Table B-6. The distinction among each group is not absolute, but it helped organize the decision process. Several methods clearly did not meet the method criteria. The descriptive LME method (Sherman and Hempel 2009) does not directly measure sensitivity to impacts. To properly adapt this method to assess environmental sensitivity and provide a ranking of planning areas would require extensive alteration to the base framework of the method. Therefore, this method was eliminated from further consideration. Ecosystem modeling methods, Atlantis and Ecopath with Ecosim, are model-based approaches that estimate energy or nutrient flow through an ecosystem. These methods have undergone extensive peer review and are used world-wide. Models have been developed for numerous ecosystems, but additional model development would be needed to cover all of the BOEM planning areas. The level of input data required to achieve quality results was deemed to be too steep. Also, adapting each model to directly assess environmental sensitivity would require large changes in the fundamental framework of each model and was agreed to be a task outside of the scope and capabilities of this project. Finally, the results of ecosystem modeling methods are not easily understood by the lay public.

Three other methods, two in the Ecological Value Mapping category (Irish Sea Pilot, Ecological Value Mapping, Vulnerable Marine Areas), and one of the Flow Chart/Decision Tree methods (Massachusetts Ocean Management Plan) were removed from further consideration. Each of these methods is directed towards small-scale MPAs siting, a concept that does not lend itself to assessing broad-scale environmental sensitivity. Furthermore, each was either directly derivative or redundant of other methods still under consideration.

The remaining methods were categorized as either ecological component ranking/scoring approaches, process-based approaches or stressor-component approaches. All of the remaining methods directly consider, or can be modified to assess ecological component relationships with various stressors, thus evaluating environmental sensitivity. The ecological component-oriented methods (to which the current BOEM Relative ESA most closely relates to) first identify and *quantify* ecological components (fauna, habitat, etc.) and then determine stressor effects on these ecological components. The defining characteristic of this group is the direct quantification of ecological components including faunal and habitat abundances and spatial extents. Environmental sensitivity in these methods is a function of the magnitude of ecological components within a study area.

Table B-6: Evaluation Matrix for Various Environmental Sensitivity Indices and Related Methods

Approach	Method Type	Specific Method	Decision
Descriptive	Large Marine Ecosystem	NOAA 2011	Eliminated as is descriptive and does not evaluate sensitivity
Ecosystem modeling	Modeling Approaches (Ecopath and Atlantis)		Eliminated as does not measure sensitivity, would require significant model development, and results not easily understood
Ecological component based with Ranking/ Scoring	BOEM Relative ESA	MMS 2007, BOEMRE 2010	Incorporate best aspects into final method
	Ecological Value Mapping	Derous et al. 2007 a,b,c	Adaptation to measure sensitivity would be labor intensive; Continue to evaluate and incorporate aspects into final method
	Ecological Value Mapping	Irish Sea Pilot (Vincent et al. 2004)	Eliminated as similar to other EVM methods; concepts incorporated in other methods
	Ecological Value Mapping	VMA (Zacharias and Gregr (2005)	Eliminated as similar to other EVM methods; concepts incorporated in other methods
	Ecological Quality Ratios	European MSFD (Borja et al, 2011)	Would require adaptation to measure sensitivity; incorporate best aspects into final method
	Environmental Vulnerability Index	Abu Dhabi Coastal Resources Atlas (ASA and RPI 2010b)	Significant adaptation needed for study purposes; incorporate best aspects into final method
	Fisheries and Ocean Canada Characterization and Risk assessment		Significant adaptation needed for study purposes; incorporate best aspects into final method
Process Based	Ecological Value Mapping	Rhode Island Special Area Management Plan (French McKay et al. 2011)	Significant adaptation needed for study purposes; incorporate best aspects into final method
	Relative Risk Model	Fock et al. 2011	Significant development needed to adapt model; incorporate best aspects into final method
Stressor component based	Flow Chart/Decision Tree	MarLIN	Directly measures sensitivity but very labor intensive to develop; incorporate best aspects into final method.
	Flow Chart/Decision Tree	Massachusetts Ocean Management Plan Approach	Eliminated as it is a siting-based process that does not measure sensitivity, with significant development needed to adapt for this project; concepts incorporated in other methods

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Table B-7: Summary of Evaluation of Methods

Method	Scientific validity (rigorous (e.g. published in peer review journal), replicable)	Evaluates sensitivity or can be adapted to do so?	Applicable to all OCS planning areas?	Can accommodate all BOEM missions including cumulative impacts	Ease of use	Output Easily understood and relevant?
BOEMRE Relative Environmental Sensitivity Analysis (BOEMRE 2010)	NOAA ESI for shoreline habitat has been used for three decades. Mainly gray literature (governmental agency reports) with some peer review Replicability requires assumptions	Yes	Yes	Yes. Method is based on aggregating component responses, and could be further developed	Labor intensive; requires a variety of data sources	Yes
Fisheries and Ocean Canada Characterization and Risk assessment (DFO)	Developed collaboratively with team of scientists, but results not published in peer reviewed journals.	Method considers stresses and impacts to vulnerable areas, so could be adapted	Yes, but models would need to be developed for each area	Yes with additional development and consideration of BOEM activities	Labor intensive	Yes
Modeling Approaches (Ecopath and Atlantis)	Ecopath: World wide use, hundreds of peer-reviewed publications. Atlantis: world wide use, some peer-reviewed publications	Ecopath: does not evaluate sensitivity; but could be adapted with additional modeling. Atlantis: does not evaluate sensitivity; but could be adapted with additional modeling.	Yes, but new models would need to be developed	Ecopath: no Atlantis: yes, but would require additional modeling.	Ecopath: Labor intensive Atlantis: labor intensive	Ecopath: results difficult to interpret. Atlantis: moderately difficult to interpret but relevant
Large Marine Ecosystems **(LME)**	No, but briefs and 4 reports are written by experts in each field and include references to peer-reviewed journals.	No, not by itself. Method is descriptive of current conditions, some aspects of which include elements sensitivity (i.e. SST warming rate and fishery exploitation status); the discussion of pollution and health of each LME is sensitivity-based	All OCS planning areas are WITHIN the larger-area LMEs	Not by itself, but perhaps if data gaps were addressed and added to supplement the LME briefs and report	Very easy to use as a descriptive tool but not set up for use as index.	Very easily understood and relevant, but does not include all pertinent information (i.e. bottom sediment, marine mammals and sea turtles, ship traffic, etc. information/analysis).
Ecological Value Mapping (EVM) **Derous et al. Approach**	Extensively published in peer reviewed journals, particularly studies out of Europe. Cited 30+ times in peer reviewed journals since 2007. Most commonly utilized environmental status assessment in peer reviewed literature. Government agencies (Mass MOP) have also used aspects of this approach. Replicability dependent on *a priori* definition of criteria questions.	Does not directly assess environmental sensitivity in its current form. Approach evaluates "ecological value". Does not currently address stressors directly. The overall concept is easily adapted to assess environmental sensitivity as the majority of basic criteria and scoring used to assess value work equally well for sensitivity.	Potentially; data poor planning areas will be a challenge. Quality in assessment may differ among planning areas dependent on data availability. Spatially explicit mapping component will be most difficult to apply in all planning areas.	Can be adapted to do so, specific methodologies will be required to address cumulative impacts. This specific approach does not include resilience as the researchers feel resilience is closely related to the assessment of future human impacts, which is not an appropriate criterion for determining the current biological value of an area. Stelzenmuller et al. (2010) have begun to address the issue of cumulative impacts within an EVM framework. Climate change estimations can potentially be assessed at planning area level using weighting mechanisms.	Extremely labor intensive. Requires spatial data on scales finer than that of entire planning area. GIS mapping skills and capabilities required. Data source needs are massive. Algorithms must be developed and applied to spatial data in order to justify mapping of components on different spatial scales. Further algorithm development will be required to address cumulative impacts and climate change.	Output is straightforward "ecological value" score mapped (color coded) over a spatial extent at a predefined grid size. Simple to understand for all stakeholders and decision makers. Individual components which contributed to overall ecological value score can be individually mapped if of interest. If approach modified to display sensitivity as opposed to value, subsequent output will be very relevant to BOEM OCS project.
Ecological Value Mapping (EVM) **Irish Sea Pilot Approach**	Mainly grey literature. Various UK government subcontractors have assessed and applied aspects of approach. Basis of assessment is generally scientifically sound. Replicability is difficult to assess, the use of (somewhat) subjectively assigned sensitivities which are utilized in matrix	One part of this approach directly assesses sensitivities of species and habitats to many different human activities/stressors.	Potentially; data poor planning areas will be a challenge. Mapping and quantification of habitat types across all planning areas will be particularly difficult.	Can be adapted to do so, specific methodologies will be required to address cumulative impacts. Stelzenmuller et al. (2010) have begun to address this issue in an EVM framework. Current approach design does not have method for summarizing overall sensitivity of an area (only component sensitivity), never mind overall cumulative	Identification of fauna/habitat/stressor relationships makes utilization extremely difficult. Spatial mapping of habitat complexes very data/research intensive. GIS mapping skills and capabilities required.	Spatially explicit "solution" maps can reflect the unique goals of researchers. However, output of approach more related to siting procedures than overall sensitivity assessment. Mapping outputs should generally be considered "easy" results to understand. Relevance will depend on how method is adapted to assess overall sensitivity and what is chosen to be displayed in map

Method	Scientific validity (rigorous (e.g. published in peer review journal), replicable)	Evaluates sensitivity or can be adapted to do so?	Applicable to all OCS planning areas?	Can accommodate all BOEM missions including cumulative impacts	Ease of use	Output Easily understood and relevant?
	setup may be questioned in replication, though no more so than other approaches which assign rankings based on attributes other than discrete numbers. Minimal citations in peer-reviewed journals. Few recent citations.			impacts. This approach includes resilience in value/sensitivity consideration.		format. Extensive tables of species/habitat sensitivities are also a useful output.
Ecological Value Mapping (EVM) **Vulnerable Marine Areas Approach**	Approach is presented in peer-reviewed journal. Well cited (40 in 7 years) in peer-reviewed journals. Replicability is high as components of interest can be defined *a priori* and then assessed for each planning area. Component overlap is easy to repeat.	Primarily identifies spatially explicit areas as highly sensitive. Can potentially be adapted to assess more cumulative sensitivity of areas. Definition of sensitivity in this approach is just overlap of a stressor and an ecological component (binary).	Applicable due to ability to define ecological characteristics of interest before beginning analysis. However, overall methodology does not seem comparatively applicable with other approaches studied. Potential difficulties in spatially mapping each stressor/component.	No discussion of cumulative impacts is given in approach. Would be difficult to utilize as summarization of multiple stressors is not even currently a part of this approach. As with all mapping approaches, the inclusion of climate change is possible with the use of modifying factors to each species/stressor sensitivity. Resilience is not a consideration of this approach.	Less labor intensive than EVM approaches outlined above, due to pre-defined ecological components of interest. Depending upon VEFs chosen, ease of use may range between quite simple and very intensive. Necessity to map every individual species/stressor relationship would be time consuming and generally data intensive.	Spatially explicit “solution” maps can reflect the goals of researchers. Current output of approach is not relevant to BOEM OCS project. Mapping outputs should generally be considered “easy” results to understand. Relevance will depend on how method is adapted to assess overall sensitivity. Output more related to siting procedures than overall sensitivity assessment.
Flow Chart/Decision Tree **MarLIN Approach**	Well documented in government grey literature. One peer reviewed article published which directly addresses methodology (12 citations). Responsible authors have numerous other related articles in peer reviewed journals. Minimal references to this approach directly in peer reviewed journals. Very extensive documentation on methodology including recommendations for QA, notes for QC, and all other critical facets of the process.	Directly evaluates environmental sensitivity of species, habitats, and species/habitat complexes.	Approach is applicable to any area of interest. Data poor regions will suffer with this approach (as with all data intensive approaches).	Approach specifically notes in documentation that it does not accommodate cumulative impacts. Post-processing work/algorithm development may allow some cumulative impact implementation in the future. Climate change may be included as another environmental factor in matrix analysis. This approach directly addresses resilience in its sensitivity analysis.	Flow chart decision making tool is simple to follow, though seemingly difficult to keep objective (requires *a priori* identification of questions and benchmarks). Sensitivity analysis very straightforward and easy to use. Compilation of environmental database required to properly utilize flow charts will be extremely labor intensive, though lack of need of spatially explicit data for each biological component (as per EVM methods) reduces information demands considerably.	Output of approach is a list of species and habitat sensitivities to each human impact. No method of summarizing species/habitat sensitivities across an area of interest makes output unwieldy and difficult to process. However, the direct output is directly relevant to the BOEM OCS study.
Flow Chart/Decision Tree **Massachusetts Ocean Management Plan Approach**	Approach is a government agency product. Few citations in peer reviewed journals. Moderate to low scientific validity due to potential oversimplification of binary scoring. High replicability due to nature of flow chart assessment and oversimplified methodology.	Directly assesses ecological value as opposed to environmental sensitivity. Ecological criteria used for evaluation of value easily adapted to describe sensitivity.	The binary flow chart scheme is applicable to all OCS planning areas. The spatially explicit portion of the approach has same data demand issues as EVM approaches.	Cumulative impacts are not discussed in this approach. Climate change may be considered in flow chart assessment, but is not included in the defined approach. Resilience is not considered in this approach.	Comparatively, ease of use is quite high. Data requirements are far less than other spatially explicit approaches. Ranking of 1 or 0 as opposed to high, mid, low, etc. makes decision making easier, and potentially more objective. With this ease of use comes reduced accuracy and scope. Spatially explicit mapping component of this approach is as labor intensive as EVM approaches.	The output is a map of spatially explicit ecological value and tables describing each species/habitats ecological value. Both of these outputs are easily understood. The potential ability to summarize these data over study areas makes them relevant the OCS project. The current output of ecological value does not perfectly translate to environmental sensitivity.
Ecological Quality Ratios - **European Marine Strategy Framework Directive (MSFD)**	Biological descriptors are calculated using methods from peer reviewed journal articles/reports. Article itself is cited 33 times in peer reviewed journal articles. However, general approach of comparing environmental status to a “reference” condition is disputed in scientific circles.	Does not evaluate environmental sensitivity, rather calculates current environmental status. Modular nature of assessment allows for potential modification to fit needs of BOEM OCS project.	Certainly applicable to all OCS planning areas. Ability to weight based on reliability of data compensates in some respect for data poor regions.	Assesses current state of cumulative impacts on a study area, but not designed to assess potential future effects. Modular nature of assessment may allow for descriptors to be combined in unique ways to potentially assess cumulative impact. No current method for assessing potential climate change impacts, but could potentially be added as another descriptor. Resilience is not currently a facet of this approach, though may be worked into biodiversity descriptor.	Assessment of each individual biological indicator/descriptor is time consuming and data hungry. However, output of each individual component is uniform in nature allowing for easy comparisons among study areas. Also allows for simple integration of each biological component into an overall status assessment for a study area. Lack of spatially explicit data needs increases overall ease of use.	Output is an environmental status assessment value (high through low). This is easily understood and allows for simple ranking of study areas as required by BOEM. General output type of environmental status is different in scope than environmental sensitivity, but may be modified to be more relevant to BOEM OCS study.
Relative Risk Model **Wiegers and Landis Approach; Fock 2011.**	This is a well-documented approach appearing in numerous peer reviewed journals as well as government and non-profit agency reports. This includes a retrospective article on approaches use 10 years after its initial proof of concept article.	Does not directly assess environmental sensitivity. Assesses ecological risk which as a concept may be easily transferable to environmental sensitivity.	Applicable to all OCS planning areas. In order to produce relative rankings among all planning areas requires the same methodology and inputs be used for each individual planning area.	The approach is well suited to addressing multiple stressors in a large geographic area. Little work has been done with working multiple stressors into “cumulative stressors”, but this approach does seem well suited to that possibility. Climate change in not a facet of this approach but may potentially be added as an additional weighting factor in the overall risk assessment ranking	The relative risk assessment theory is rather straightforward and simple to use. Numerous studies have presented clear adaptations with methodologies and algorithms for producing risk rankings. Creation of database to properly conduct risk assessment will be most time	The output is a graph of risk rankings for each study area, which is further broken down into simplified groupings of high, medium and low risks. This output is directly what is requested by the BOEM OCS project.

Method	Scientific validity (rigorous (e.g. published in peer review journal), replicable)	Evaluates sensitivity or can be adapted to do so?	Applicable to all OCS planning areas?	Can accommodate all BOEM missions including cumulative impacts	Ease of use	Output Easily understood and relevant?
				mechanisms.	consuming portion of this approach.	
Environmental Vulnerability Index (EVI) **Abu Dhabi Coastal Resources Atlas approach**	Well documented in government grey literature but no citations in peer reviewed literature. Replicable approach to calculating sensitivity from recovery and exposure including detailed citations. Easily replicable approach to calculating vulnerability from sensitivity, value, and risk. Interesting approach to incorporating overall relative sensitivity and value and patch-specific value and risk.	Directly addresses environmental sensitivity as a function of exposure, potentially adverse ecological effects, and recovery.	Potentially. Approach is spatially explicit and data intensive, but also provides alternative algorithms that may help in data poor areas.	Adaptation of existing methodology will be required to address cumulative impacts. Also will require implementation of method to address overall sensitivity of an area. Use of recovery time in calculation of sensitivity provides good proxy for resilience. Climate change partially accounted through definition of stressors.	Generation of high resolution habitat data may be difficult to replicate at larger spatial scale. Calculation of sensitivity will require extensive literature review for each habitat/stressor combination. Algorithms for calculating Vulnerability are simple and easily applied.	Output is tabular definition of sensitivity each habitat/stressor combination and value for each habitat type. Relative sensitivity and value presented on 0 to 4 and 1-4 scales that should be considered ordered semi-nominal values. Algorithms for on-the-fly calculation of Vulnerability provided and results in normalized results on the original0 to 4 scale. Output also easily presented in map form.

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The ecological component methods had a number of advantages, including:

- Flexibility, allowing for both categorical and empirical data inputs;
- Simplicity, not overly reliant on complex statistical methods and algorithms;
- Low requirements for large arrays of measured variables, constants, and coefficients; and
- Relatively easy to apply to large matrices of ecological components and impacts.

Methods in the second group are process based. The process-based model approach is an intensive modeling approach that develops complex equations that rely on detailed, geospatial data. The advantage of this approach is that it is based on empirical data, with systematic and quantitative assessments used to develop sensitivity which do not rely on the arbitrary assignment of scores or ranks. The method is highly specialized to assess specific ecological risks and thus would be difficult to apply to a large matrix of ecological components and impacts. As the method has only been employed in small scale areas, it would require significant data input and algorithm development to apply to the BOEM OCS planning areas. The scale of the method, its intensive data requirements, and the extensive development time required would make it impractical for this study.

In the third group are methods that are described as stressor-component oriented. These methods primarily identify stressors and then assess ecological components based on each stressor. These methods are less concerned with the quantification of individual ecological components and are more presence/absence based concerning fauna/habitats. Environmental sensitivity in these methods is a function of the magnitude of stressors on each individual ecological component. An advantage of these methods is that they directly evaluate sensitivity. However, while individual sensitivities for species and habitats are evaluated, there is no means to summarize them across an area of interest. These methods would require significant development time to apply to this project.

In addition to reviewing the evaluations of the remaining methods, several assessment questions were used to further assess each method. Group consensus from the Study Team on each question is summarized for each.

1. *Should three methods be selected that represent disparate ends of the method spectrum?* Covering a wide spectrum of methods is necessary. However, the width and breadth of the thirteen methods that were assessed is too large and the far ends of the spectrum are not in line with the overall goals of the project. With a reduction in the number of methods to consider, disparate ends of this amended spectrum should be considered.
2. *Should the original ESA be included as the default, to be amended to fit our needs?* The original BOEM ESA method should be considered as a default framework, to be amended for at least one of the final suggested methods.

3. *Is it important that the method explicitly address sensitivity?* It is critical that assessment of environmental sensitivity be a capability of a method. Due to the wide range of definitions of sensitivity, it is not necessary that the method, in its original setup explicitly address sensitivity, just so long as it may be amended to do so.
4. *Is it important that the method explicitly address cumulative impacts?* A method for addressing cumulative impacts as they relate to environmental sensitivity is important. However, a method in its original form need not directly address this issue.
5. *Does the method have to be useable "off the shelf" or would we consider modification, and if so to what degree?* None of the methods considered are usable "off the shelf," all would require substantial modification, more than would be acceptable.
6. *Is it essential that the method be able to incorporate regulatory considerations?* Weighting of environmental sensitivity by regulatory considerations is considered critical.
7. *How should model scale affect our decision process (e.g., some methods are "micro scale" which would need to be combined to reach the OCS planning area scale; others are large scale and more easily adaptable to OCS planning areas)?* Scaling is going to be an issue of concern given the immense scale of the OCS planning areas. The capability of a method to be scaled up is pivotal. Numerous methods were not considered for evaluation based on this attribute.
8. *One suggestion is to take pieces of the various models and combine-especially if the methods calculate a value only. How would we do that?* Taking pieces from each method will be necessary.

The Study Team decided that ecosystem component ranking and scoring methods would be most appropriate for this study. These methods have many relatively similar characteristics, with each method having strengths and weaknesses. However, no one method met all criteria without modification. The ecological value mapping methods as used in the Rhode Island Special Area Management Plan and Fisheries Ocean Canada have been developed to identify valuable marine areas over a small spatial area. They would need to be adapted to assess environmental sensitivity; the methods are already labor intensive and would require too many resources to meet the project timeline. Similarly, the EVI, which does address environmental sensitivity, is also data-intensive over a small spatial scale. Admittedly, BOEM's current Relative ESA, developed for oil and gas, would also need re-tooling to encompass all of BOEM's activities. The Study Team decided that since there was no one method that met the project goals, a new method, termed the "purpose-built method," which takes the best aspects from the existing methods, would be developed. The new method would have a "practical" and "ideal" option. The ideal option would be designed without consideration of data, time, or resource limitations. It would include all identified ecological components (fauna, habitats, and ecosystem metrics) and their best descriptive attributes. The practical option would be designed to be achievable for BOEM’s immediate needs. It will include representative attributes from those ecological components. The Study Team also decided that the method should incorporate aspects of both fauna and habitats. Facets of all reviewed methods (including concepts such as spatial scale, criteria and parameter selection, and data sourcing) would be considered in the final method design.

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APPENDIX C: FAUNAL AND HABITAT SELECTION

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Table C-1: Species Selected for Use in the RESA Model

Ecological Component	Parameter Selection Categories	OCS Ecoregion	1	2	3	4	5	6	7	8	9
		Name	NE US Continental Shelf	SE US Continental Shelf	Eastern Gulf of Mexico	Western Gulf of Mexico	California Current	Washington/Oregon	Gulf of Alaska	East Bering Sea	Chukchi and Beaufort Seas
		Planning Areas	Planning Areas 1,2	Planning Areas 3,4	Planning Area 5	Planning Areas 6,7	Planning Areas 8,9,10	Planning Area 11	Planning Areas 12,13,14,15	Planning Areas 16,17,18,19, 20,21,22,23	Planning Areas 24,25,26
Mammals and Sea Turtles - 5 total	Conservation Importance	Species 1	North Atlantic right Whale	North Atlantic right whale	Sperm whale	Sperm whale	Leatherback sea turtle	Leatherback sea turtle	North Pacific right whale	North Pacific right whale	Polar bear Chukchi/Bering Sea stock
		Species 2	Humpback whale	Florida manatee, FL stock FL subspecies	Green sea turtle	Hawksbill sea turtle	Fin whale	Southern resident killer whale	Humpback whale	Steller sea lion	Bowhead whale
		Species 3	Fin whale	Loggerhead sea turtle	Hawksbill sea turtle	Kemp's ridley sea turtle	Humpback whale CA/OR/WA stock	Sperm whale	Sperm whale	Humpback whale	Pacific walrus
		Species 4	Leatherback sea turtle	Green sea turtle	Florida manatee, FL stock FL subspecies	Green sea turtle	Sperm whale	Humpback whale CA/OR/WA stock	Steller sea lion	Sperm whale	Ringed seal
	Ecological Role	Species 1	Short-beaked common dolphin	Atlantic spotted dolphin	Pantropical spotted dolphin	Pantropical spotted dolphin	Short beaked common dolphin CA/OR/WA stock	Dall's porpoise	Northern fur seal	Northern fur seal	Beluga whale Chukchi and Bering Sea stock
Birds - 4 total	Conservation Importance	Species 1	Roseate Tern	Wood Stork	Wood Stork	Whooping Crane	Snowy Plover	Snowy Plover	Steller's Eider	Steller's Eider	Steller's Eider
		Species 2	Red Knot	Roseate Tern	Piping Plover	Piping Plover	Marbled Murrelet	Marbled Murrelet	Short-tailed Albatross	Short-tailed Albatross	Spectacled Eider
	Ecological Role	Species 1	Double-crested Cormorant	Double-crested Cormorant	Double-crested Cormorant	Double-crested Cormorant	Western Gull	Glaucous-winged Gull	Glaucous-winged Gull	Glaucous-winged Gull	Glaucous Gull
		Species 2	Wilson's Storm-Petrel	Wilson's Storm-Petrel	Magnificent Frigatebird	Magnificent Frigatebird	Sooty Shearwater	Sooty Shearwater	Marbled Murrelet	Pigeon Guillemot	Red-necked Phalarope
Fish - 4 total	Conservation Importance	Species 1	Atlantic sturgeon	Atlantic sturgeon	Smalltooth sawfish	Gulf sturgeon	Steelhead trout	Bocaccio	Pacific herring	N/A	N/A
	Fisheries Importance	Species 1	Menhaden	Spanish mackerel	Striped mullet	Gulf menhaden	Pacific sardine	Pacific hake (whiting)	Walleye pollock	Walleye pollock	Arctic cisco
		Species 2	Atlantic mackerel	Vermillion snapper	Red grouper	Red snapper	Chub mackerel	Albacore tuna	Pink salmon	Pink salmon	Dolly varden
	Ecological Role	Species 1	Atlantic herring	Striped mullet	Bay anchovy	Atlantic croaker	Northern anchovy	Pacific sardine	Arrowtooth flounder	Atka mackerel	Arctic cod
Invertebrates – 4 total	Fisheries Importance	Species 1	Blue crab	Blue crab	Pink shrimp	Brown shrimp	California market squid	Dungeness crab	Golden king crab	Golden king crab	Snow crab
		Species 2	American lobster	White shrimp	Blue crab	White shrimp	Dungeness crab	Pacific oyster	Tanner crab	Snow crab	Blue king crab
	Ecological Role	Species 1	Surf clam	Brown shrimp	Florida stone crab	Oyster	Pacific Ocean shrimp	Pacific Ocean shrimp	Euphausiid (*Thysanoessa inermis*)	Euphausiid (*Thysanoessa inermis*)	Euphausiid (*Thysanoessa raschii*)
		Species 2	Squid	Oyster	Oyster	Blue crab	Red sea urchin	Red sea urchin	Baltic macoma clam	Baltic macoma clam	Baltic macoma clam

Table C-2: Habitats Selected for Use in the RESA Model

Ecological Component	Parameter Selection Categories		OCS Ecoregion	1	2	3	4	5	6	7	8	9
			Name	**NE US Continental Shelf**	**SE US Continental Shelf**	**Eastern Gulf of Mexico**	**Western Gulf of Mexico**	**California Current**	**Washington/Oregon**	**Gulf of Alaska**	**East Bering Sea**	**Chukchi and Beaufort Seas**
			Planning Areas	**Planning Areas 1,2**	**Planning Areas 3,4**	**Planning Area 5**	**Planning Areas 6,7**	**Planning Areas 8,9,10**	**Planning Area 11**	**Planning Areas 12,13,14,15**	**Planning Areas 16,17,18,19, 20,21,22,23**	**Planning Areas 24,25,26**
Estuarine	Benthic		1	Aquatic Vascular Vegetation (AVV)	AVV	Mollusk Reef	AVV	AVV	AVV (Eelgrass)	AVV (Eelgrass)	AVV (Eelgrass)	Benthic Macroalgae
	Water Column		1	Open Water	Open Water	Open Water	Open Water	Open Water	Open Water	Coastal Band	Coastal Band	Coastal Band
Marine	Nearshore/Offshore	Benthic	2	Banks	Shallow/Mesophotic Coral	AVV	FUS	FUS	FUS	Cobble/Rock	FUS	FUS
				Submarine Canyons	Worm Substrate (Sabellariid)	Live Hard Bottom	Banks (Flower Garden Reefs)	Submarine Canyons	Boulder	FUS	Shelf Break	Boulder
		Pelagic	1	Surface/Photic Zone	Algal Rafts (*Sargassum*)	Algal Rafts (*Sargassum*)	Surface/Photic Zone	Algal Rafts (Kelp)	Algal Rafts (Kelp)	Algal Rafts (Kelp)	Pack Ice	Ice
	Oceanic	Benthic	2	Deep/Coldwater Coral	Deep/Coldwater Coral	Deep/Coldwater Coral	Deep/Coldwater Coral	Deep/Coldwater Coral	Deep/Coldwater Coral	Deep/Coldwater Coral	Deep/Coldwater Coral	Deep/Coldwater Coral
				Slope	Fine Unconsolidated Sediment (FUS)	Seeps	Seeps	Seamounts	Seamounts	Seamounts	Ridge/Rock	FUS

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For Tables C-3 through C-11, BNA refers to the Birds of North America accounts for birds available on-line at http://bna.birds.cornell.edu/bna/ - each species has an individual account cited in the references below.

Table C-3: Species List and Rationale for Planning Areas 1 and 2 – Northeastern U.S. Continental Shelf

Selection Criteria	Species	Selection Rationale	Reference
Mammals and Sea Turtles- 5 total			
Conservation Importance	North Atlantic Right Whale	Endangered; Critical habitat; year-round resident; foraging, nursery, migratory area; much information available	Waring et al., 2012
Conservation Importance	Humpback Whale	Endangered; year-round resident; foraging area; much information available	Waring et al., 2012
Conservation Importance	Fin Whale	Endangered; highly abundant; year-round resident; much information available	Waring et al., 2012
Conservation Importance	Leatherback turtle	Endangered; foraging, migratory area, some satellite telemetry studies	NMFS 2007; NMFS and USFWS 1992; James et al., 2005
Ecological Role	Short-beaked common dolphin	Very high abundance estimate (120,743)	Waring et al., 2012
Birds - 4 total			
Conservation Importance	Roseate Tern	Federally Endangered. Coastal, near shore and pelagic. Shallow plunge diver.	eBird 2012, BNA (Gochfeld et al 1998)
Conservation Importance	Red Knot	Federally listed as candidate species. Primarily coastal but also flies near shore when moving from one foraging area to another. Also offshore during migration	eBird 2012, BNA (Harrington 2001)
Ecological Role	Double-crested Cormorant	Most common saltwater bird with habitat use that complements Conservation Importance Species and storm-petrel (swimming, deeper diving species than others). Coastal, near shore.	eBird 2012, BNA (Hatch and Weseloh 1999).
Ecological Role	Wilson's Storm-Petrel	Most common seabird with habitat use and behavior that complements Conservation Importance Species and cormorant (found further offshore, different flight behavior than tern or knot – forages by gleaning prey off water surface).	eBird 2012, Howell 2012
Fish - 4 total			
Conservation	Atlantic	The only endangered fish species occurring in this OCS Ecoregion are the Atlantic sturgeon,	NMFS 2012a; IUCN

Selection Criteria	Species	Selection Rationale	Reference
Importance	sturgeon	the shortnose sturgeon, and the Gulf of Maine population of Atlantic salmon. Of these, the Atlantic sturgeon has the highest IUCN Red List status and is the most widely distributed within the OCS Ecoregion.	2012
Fisheries Importance	Menhaden	Based on combined 2000-2010 commercial landings for the Mid-Atlantic and North Atlantic, this species had the highest landings by weight.	NMFS 2012c
Fisheries Importance	Atlantic mackerel	Based on combined 2000-2010 commercial landings for the Mid-Atlantic and North Atlantic, this species had the third highest landings by weight. It is also a popular recreational species (sixth highest in combined 2000-2010 recreational landings by weight for the Mid-Atlantic and North Atlantic).	NMFS 2012c; NMFS 2012d
Ecological Role	Atlantic herring	This species is highly abundant (second highest in combined 2000-2010 commercial landings by weight for the Mid-Atlantic and North Atlantic), and an important forage species for marine mammals, birds, and fish.	NMFS 2012c; ASMFC 2012
Invertebrates - 4 total			
Fisheries Importance	American lobster	Based on combined 2000-2010 commercial landings for the Mid-Atlantic and North Atlantic, this species had the highest landings by weight.	NMFS 2012c
Fisheries Importance	Blue crab	Based on combined 2000-2010 commercial landings for the Mid-Atlantic and North Atlantic, this species had the second highest landings by weight.	NMFS 2012c
Ecological Role	Surf clam	This species is highly abundant (third highest in 2000-2010 commercial landings by weight for this OCS Ecoregion) and an important forage species for a variety of predators, including snails, sea stars, crabs, and fish (e.g., haddock and Atlantic cod).	NMFS 2012c; Cargnelli et al., 1999
Ecological Role	Squid	This species is highly abundant (fifth highest in 2000-2010 commercial landings by weight for this OCS Ecoregion), and an important forage species for pelagic and demersal fish, marine mammals, and diving birds.	NMFS 2012c; Jacobson 2005

Table C-4: Species List and Rationale for Planning Areas 3 and 4 – Southeastern U.S. Continental Shelf

Selection Criteria	Species	Selection Rationale	Reference
Mammals and Sea Turtles- 5 total			
Conservation Importance	North Atlantic Right Whale	Endangered; Critical habitat; year-round resident; foraging, nursery, migratory area; much information available	Waring et al., 2012
Conservation Importance	Florida manatee	Endangered; designated FL state and federal protection areas	USFWS 2001
Conservation Importance	Loggerhead turtle	Threatened; 2nd largest nesting site in the world in FL; year-round in FL	NMFS and USFWS 2008
Conservation Importance	Green turtle	Endangered in FL, Threatened in all other areas; major nesting areas in FL	NMFS and USFWS 2007; NMFS and USFWS 1991
Ecological Role	Atlantic spotted dolphin	Highest population estimate (FL-MD = 47,400)	Waring et al., 2012
Birds- 4 total			
Conservation Importance	Wood Stork	Federally Endangered. Coastal wetlands, estuaries, bays, shallow water.	eBird 2012, BNA
Conservation Importance	Roseate Tern	Federally Threatened. Coastal, near shore and pelagic. Shallow plunge diver.	eBird 2012, BNA (Gochfeld et al 1998)
Ecological Role	Double-crested Cormorant	Most common saltwater bird with habitat use that complements Conservation Importance Species and storm-petrel (swimming, deeper diving species than others). Coastal, near shore.	eBird 2012, BNA (Hatch and Weseloh 1999).
Ecological Role	Wilson's Storm-Petrel	Most common seabird with habitat use and behavior that complements Conservation Importance Species and cormorant (found further offshore, different flight behavior than tern – forages by gleaning prey off water surface).	eBird 2012, Howell 2012
Fish- 4 total			
Conservation Importance	Atlantic sturgeon	The only endangered fish species occurring in this OCS Ecoregion are the Atlantic sturgeon and the shortnose sturgeon. Of these, the Atlantic sturgeon has the highest IUCN Red List status and is the most widely distributed within the OCS Ecoregion.	NMFS 2012a; IUCN 2012
Fisheries	Spanish	Based on 2000-2010 commercial landings for the South Atlantic, this species had the highest landings by	NMFS 2012c

Selection Criteria	Species	Selection Rationale	Reference
Importance	mackerel	weight.	
Fisheries Importance	Vermillion snapper	Based on combined 2000-2010 commercial landings for the Mid-Atlantic and North Atlantic, this species had the fourth highest landings by weight. It is also a recreational species.	NMFS 2012c; NMFS 2012d
Ecological Role	Striped mullet	This species is highly abundant (second highest in 2000-2010 commercial landings by weight for the South Atlantic), and an important forage species for birds, fish, sharks, and porpoises.	NMFS 2012c; NCDMF 2010
Invertebrates- 4 total			
Fisheries Importance	Blue crab	Based on 2000-2010 commercial landings for the South Atlantic, this species had the highest landings by weight.	NMFS 2012c
Fisheries Importance	White shrimp	Based on 2000-2010 commercial landings for the South Atlantic, this species had the second highest landings by weight.	NMFS 2012c
Ecological Role	Brown shrimp	This species is highly abundant (fourth highest in 2000-2010 commercial landings by weight for this OCS Ecoregion), and an important prey item for many fish and large crustaceans.	NMFS 2012c; Larson et al., 1989
Ecological Role	Oyster	This species is highly abundant (ninth highest in 2000-2010 commercial landings by weight for this OCS Ecoregion), and has numerous predators, including birds and other marine invertebrates. Oyster reefs also provide shelter and habitat for many other species.	NMFS 2012c; Burrell, 1986

***Note**: In this application of the model, there was no allotment for conservation status invertebrates. However, there are several conservation species for this OCS Ecoregion: elkhorn coral, staghorn coral, ivory tree coral, and queen conch. Elkhorn and staghorn corals are listed as threatened and have critical habitat designated in south Florida, Puerto Rico, and the U.S. Virgin Islands. The queen conch is a candidate species throughout its range, which includes the Gulf of Mexico and from Florida east to Bermuda. The ivory tree coral is a species of concern. The main population of concern for the ivory tree coral is located off east-central Florida in the Oculina Banks area (NMFS 2012b). Shallow mesophotic and Deep/coldwater Corals have been included as habitats in this OCS Ecoregion.

Table C-5: Species List and Rationale for Planning Area 5 – Eastern Gulf of Mexico

Selection Criteria	Species	Selection Rationale	Reference
Mammals and Sea Turtles- 5 total			
Conservation Importance	Sperm whale	Only endangered whale species to occur in relatively high abundance	Waring et al., 2012
Conservation Importance	Loggerhead turtle	Threatened; Most abundant turtle species	NMFS and USFWS 2008
Conservation Importance	Green turtle	Endangered in FL, Threatened in all other areas; major nesting areas in FL	NMFS and USFWS 2007; NMFS and USFWS 1991
Conservation Importance	Hawksbill turtle	Endangered; Rely on coral reefs for food and protection	NMFS and USFWS 1993
Ecological Role	Pantropical spotted dolphin	Highest abundance estimate (34,067)	Waring et al., 2012
Birds- 4 total			
Conservation Importance	Wood Stork	Federally Endangered. Coastal wetlands, estuaries, bays, shallow water.	eBird 2012, BNA, Coulter, et al.,1999
Conservation Importance	Piping Plover	Federally Endangered. Beaches and off shore during migration.	eBird 2012, BNA (Elliott-Smith and Haig 2004
Ecological Role	Double-crested Cormorant	Most common saltwater bird with habitat use that complements Conservation Importance Species and frigatebird (swimming, deeper diving species than others). Coastal, near shore.	eBird 2012, BNA (Hatch and Weseloh1999)
Ecological Role	Magnificent Frigatebird	Most common seabird with habitat use that complements Conservation Importance Species and cormorant (Kleptoparasite. Coastal but also further offshore).	eBird 2012, BNA (Diamond and Schreiber 2002)
Fish- 4 total			
Conservation Importance	Smalltooth sawfish	The only endangered fish species occurring in this OCS Ecoregion are the largetooth sawfish and the smalltooth sawfish. They both have the same IUCN Red List ranking of Critically Endangered. The smalltooth sawfish was selected because the largetooth sawfish has not been found in U.S. waters in 50 years.	NMFS 2012a; IUCN 2012
Fisheries	Striped	Based on 2000-2010 commercial landings for the Eastern Gulf of Mexico, this species had the highest	NMFS 2012c

Selection Criteria	Species	Selection Rationale	Reference
Importance	mullet	landings by weight.	
Fisheries Importance	Red grouper	Based on 2000-2010 commercial landings for Eastern Gulf of Mexico, this species had the second highest landings by weight. This species also contributes substantially to sport angling.	NMFS 2012c; NMFS 2012d
Ecological Role	Bay anchovy	This species is one of the most abundant fish in the northeastern Gulf of Mexico, even in areas experiencing environmental stress. Due to their small size and great numbers, bay anchovies are an important forage species for larger fish and seabirds.	Robinette, 1983
Invertebrates- 4 total			
Fisheries Importance	Pink shrimp	Based on 2000-2010 commercial landings for the Eastern Gulf of Mexico, this species had the highest landings by weight.	NMFS 2012c
Fisheries Importance	Blue crab	Based on 2000-2010 commercial landings for the Eastern Gulf of Mexico, this species had the second highest landings by weight.	NMFS 2012c
Ecological Role	Florida stone crab	Florida stone crab landings rank third among the invertebrate fisheries landings in the Eastern Gulf of Mexico, and only the claws are harvested. Larval stone crabs are subject to predation by plankton-feeding organisms and juvenile stone crabs are preyed upon by groupers, sea bass, and many other species of large fish.	NMFS 2012c Lindberg and Marshall, 1984;
Ecological Role	Oyster	This species is highly abundant (fifth highest in 2000-2010 commercial landings by weight for this OCS Ecoregion), and has numerous predators, including birds and other marine invertebrates. Oyster reefs also provide shelter and habitat for many other species.	NMFS 2012c; TPW 2012; LDWF 2012

***Note:** In this application of the model, there was no allotment for conservation status invertebrates. However, there are several conservation species for this OCS Ecoregion: elkhorn coral, staghorn coral, and queen conch. Elkhorn and staghorn corals are listed as threatened and have critical habitat designated in south Florida, Puerto Rico, and the U.S. Virgin Islands. The queen conch is a candidate species throughout its range, which includes the Gulf of Mexico and from Florida east to Bermuda (NMFS 2012b). Live hard bottom and Deep/coldwater Corals have been included as habitats in this OCS Ecoregion.

Table C-6: Species List and Rationale for Planning Areas 6 and 7 – Western Gulf of Mexico

Selection Criteria	Species	Selection Rationale	Reference
Mammals and Sea Turtles- 5 total			
Conservation Importance	Sperm whale	Only endangered whale species to occur in relatively high abundance	Waring et al., 2012
Conservation Importance	Green turtle	Threatened	NMFS and USFWS 2007; NMFS and USFWS 1991
Conservation Importance	Kemp's turtle	Endangered; TX = 1 of 2 nesting areas in the world	NMFS, USFWS, and SEMARNAT, 2011
Conservation Importance	Hawksbill turtle	Endangered; Rely on coral reefs for food and protection	NMFS and USFWS 1993
Ecological Role	Pantropical spotted dolphin	Highest abundance estimate (34,067)	Waring et al., 2012
Birds- 4 total			
Conservation Importance	Whooping Crane	Federally Endangered. Coastal wetlands, estuaries, bays, shallow water.	eBird 2012, BNA
Conservation Importance	Piping Plover	Federally Endangered. Beaches and near shore. Off shore during migration.	eBird 2012, BNA (Elliott-Smith and Haig 2004)
Ecological Role	Double-crested Cormorant	Most common saltwater bird with habitat use that complements Conservation Importance Species and frigatebird (swimming, deeper diving species than others). Coastal, near shore.	eBird 2012, BNA (Hatch and Weseloh1999)
Ecological Role	Magnificent Frigatebird	Most common seabird with habitat use that complements Conservation Importance Species and cormorant (Kleptoparasite. Coastal but also further offshore).	eBird 2012, BNA (Diamond and Schreiber 2002)
Fish- 4 total			
Conservation Importance	Gulf sturgeon	The only ESA-listed species occurring in this OCS Ecoregion are the endangered largetooth sawfish and the threatened Gulf sturgeon. Despite its higher ESA status, largetooth sawfish was not selected because it has not been found in U.S. waters in 50 years.	NMFS 2012a
Fisheries Importance	Gulf menhaden	Based on 2000-2010 commercial landings for the Western Gulf of Mexico, this species had the	NMFS 2012c

Selection Criteria	Species	Selection Rationale	Reference
		highest landings by weight.	
Fisheries Importance	Red snapper	Based on 2000-2010 commercial landings for the Western Gulf of Mexico, this species had the fourth highest landings by weight. It is also a popular recreational species (fifth highest landings by weight).	NMFS 2012c; NMFS 2012d
Ecological Role	Atlantic croaker	Groundfish dominate the marine fish communities of the Western Gulf of Mexico and the Atlantic Croaker dominates the groundfish community. They feed on a variety of organisms on and in surface sediment layers and are preyed upon by larger fish.	Lassuy, 1983
Invertebrates- 4 total			
Fisheries Importance	Brown shrimp	Based on 2000-2010 commercial landings for the Western Gulf of Mexico, this species had the highest landings by weight.	NMFS 2012c
Fisheries Importance	White shrimp	Based on 2000-2010 commercial landings for the Western Gulf of Mexico, this species had the second highest landings by weight.	NMFS 2012c
Ecological Role	Blue crab	This species is highly abundant (third highest in 2000-2010 commercial landings by weight for this OCS Ecoregion), and an important prey item for many fish and large crustaceans.	NMFS 2012c; Larson et al., 1989
Ecological Role	Oyster	This species is highly abundant (fourth highest in 2000-2010 commercial landings by weight for this OCS Ecoregion), and has numerous predators, including birds and other marine invertebrates. Oyster reefs also provide shelter and habitat for many other species.	NMFS 2012c; TPW 2012; LDWF 2012

***Note**: In this application of the model, there was no allotment for conservation status invertebrates. However, there is a candidate species for this OCS Ecoregion. The queen conch is a candidate species throughout its range, which includes the Gulf of Mexico and from Florida east to Bermuda (NMFS 2012b).

Table C-7: Species List and Rationale for Planning Areas 8, 9, and 10 – California Current

Selection Criteria	Species	Selection Rationale	Reference
Mammals and Sea Turtles- 5 total			
Conservation Importance	Humpback Whale	Endangered; with information available	Carretta et al., 2012
Conservation Importance	Fin Whale	Endangered; with information available	Carretta et al., 2012
Conservation Importance	Leatherback turtle	Endangered; Critical habitat	NMFS and USFWS 1998; NMFS 2012e
Conservation Importance	Steller sea lion	Threatened; Critical habitat	NMFS 2008
Ecological Role	Short-beaked common dolphin	Highest population estimates (411,211)	Carretta et al., 2012
Birds- 4 total			
Conservation Importance	Least Tern	Federally Endangered. Coastal and near shore. Shallow plunge diver.	eBird 2012, BNA (Thompson et al. 1997)
Conservation Importance	Marbled Murrelet	Federally Threatened. Near and off shore. Feeds by shallow and deeper diving.	eBird 2012, BNA (Nelson 1997)
Ecological Role	Western Gull	Most common saltwater bird with habitat use that complements Conservation Importance Species and shearwater (near shore, surface and beach feeder). Coastal, near shore.	eBird 2012, BNA (Pierotti and Annett 1995)
Ecological Role	Sooty Shearwater	Most common seabird with habitat use and behavior that complements Conservation Importance Species and gull (found further offshore, different flight behavior than tern or murrelet – forages by shallow dives).	eBird 2012, Howell 2012
Fish- 4 total			
Conservation Importance	Steelhead trout	The only endangered species/stock along the coast of California are the Central California coast population of coho salmon and the Southern California population of steelhead trout. After considering IUCN status and distribution, these two species resulted in a tie. Steelhead trout was ultimately selected based on the fact that it has more ESA-listed stocks in this OCS Ecoregion than coho salmon.	NMFS 2012a; IUCN 2012

Selection Criteria	Species	Selection Rationale	Reference
Fisheries Importance	Pacific sardine	Based on 2000-2010 commercial landings for California, this species had the highest landings by weight.	NMFS 2012c
Fisheries Importance	Chub mackerel	Based on 2000-2010 commercial landings for California, this species had the third highest landings by weight.	NMFS 2012c
Ecological Role	Northern anchovy	This species is abundant (second highest in 2000-2010 commercial landings by weight for California), and an important forage species for a variety of fishes, mammals, and birds.	NMFS 2012c; CDFG 2012
Invertebrates- 4 total			
Fisheries Importance	California market squid	Based on 2000-2010 commercial landings for California, this species had the highest landings by weight.	NMFS 2012c
Fisheries Importance	Dungeness crab	Based on 2000-2010 commercial landings for California, this species had the second highest landings by weight.	NMFS 2012c
Ecological Role	Pacific ocean shrimp	This species is highly abundant (fourth highest in 2000-2010 commercial landings by weight for this OCS Ecoregion) and have been reported as a prey item for many fish species.	NMFS 2012c; CDFG 2008
Ecological Role	Red sea urchin	Urchins are abundant (third highest in 2000-2010 commercial landings by weight for this OCS Ecoregion) and play an important role in structuring kelp forest communities. They also are an important prey item for sea otters, lobsters, sea stars, crabs, and fish. Of the two main urchin species in this OCS Ecoregion, the red sea urchin was selected as the representative urchin species because it supports the largest fishery.	NMFS 2012c; CDFG 2004

*Note: In this application of the model, there was no allotment for conservation status invertebrates. However, there are several conservation species for this OCS Ecoregion: black abalone, white abalone, green abalone, and pink abalone. Black abalone and white abalone are listed as endangered through their range (California and Mexico), and the black abalone has critical habitat designated in California. Green abalone and pink abalone are species of concern from Point Conception, CA to Mexico (NMFS 2012b).

Table C-8: Species List and Rationale for Planning Area 11 – Washington/Oregon

Selection Criteria	Species	Selection Rationale	Reference
Mammals and Sea Turtles- 5 total			
Conservation Importance	Humpback Whale	Endangered with information available	Carretta et al., 2012
Conservation Importance	Fin Whale	Endangered; with information available	Carretta et al., 2012
Conservation Importance	Leatherback turtle	Endangered; Critical habitat	NMFS and USFWS 1992; NMFS, NOAA 2012e
Conservation Importance	Southern resident killer whale	Endangered; with information available	Carretta et al., 2012
Ecological Role	Dall's porpoise	Highest population estimate (42,000)	Carretta et al., 2012
Birds- 4 total			
Conservation Importance	Snowy Plover	Federally Threatened. Beaches and near shore when moving between foraging areas.	eBird 2012, BNA (Gary et al.2009)
Conservation Importance	Marbled Murrelet	Federally Threatened. Near and off shore. Feeds by shallow and deeper diving.	eBird 2012, BNA (Nelson 1997)
Ecological Role	Glaucous-winged Gull	Most common saltwater bird with habitat use that complements Conservation Importance Species and shearwater (near shore, surface and beach feeder). Coastal, near shore.	eBird 2012, BNA (Gilchrist 2001,Hayward and Verbeek 2008)
Ecological Role	Sooty Shearwater	Most common seabird with habitat use and behavior that complements Conservation Importance Species and gull (found further offshore, different flight behavior than tern or murrelet – forages by shallow dives).	eBird 2012, Howell 2012
Fish- 4 total			
Conservation Importance	Bocaccio	The only endangered species/stock along the coast of Washington/Oregon is the Puget Sound/Georgia Basin stock of bocaccio. There are other endangered stocks in the OCS Ecoregion (i.e., sockeye and chinook salmon), but they were not considered because the stocks are associated with inland portions of rivers.	NMFS 2012a
Fisheries Importance	Pacific hake (whiting)	Based on 2000-2010 commercial landings for Washington/Oregon, this species had the highest	NMFS 2012c

Selection Criteria	Species	Selection Rationale	Reference
		landings by weight.	
Fisheries Importance	Albacore tuna	Based on 2000-2010 commercial landings for Washington/Oregon, this species had the third highest landings by weight.	NMFS 2012c
Ecological Role	Pacific sardine	This species is abundant (second highest in 2000-2010 commercial landings by weight for Washington/Oregon), and an important forage species for a variety of fishes, mammals, and birds.	NMFS 2012c; Cascorbi, 2004
Invertebrates- 4 total			
Fisheries Importance	Dungeness crab	Based on 2000-2010 commercial landings for Washington/Oregon, this species had the highest landings by weight.	NMFS 2012c
Fisheries Importance	Pacific oyster	Based on 2000-2010 commercial landings for Washington/Oregon, this species had the third highest landings by weight.	NMFS 2012c
Ecological Role	Pacific ocean shrimp	This species is highly abundant (second highest in 2000-2010 commercial landings by weight for this OCS Ecoregion) and have been reported as a prey item for many fish species.	NMFS 2012c; CDFG 2008
Ecological Role	Red sea urchin	Urchins are abundant (sixth highest in 2000-2010 commercial landings by weight for this OCS Ecoregion) and play an important role in structuring kelp forest communities. They also are an important prey item for sea otters, lobsters, sea stars, crabs, and fish. . Of the two main urchin species in this OCS Ecoregion, the red sea urchin was selected as the representative urchin species because it supports the largest fishery.	NMFS 2012c; CDFG 2004; ODFW 2011

***Note:** In this application of the model, there was no allotment for conservation status invertebrates. However, there is a species of concern for this OCS Ecoregion. The pinto abalone is a species of concern from Sitka, AK south to Point Conception, CA (NMFS 2012b).

Table C-9: Species List and Rationale for Planning Areas 12, 13, 14, and 15 – Gulf of Alaska

Selection Criteria	Species	Selection Rationale	Reference
Mammals and Sea Turtles- 5 total			
Conservation Importance	North Pacific Right Whale	Endangered; Critical habitat	Allen and Angliss, 2012
Conservation Importance	Sperm whale	Endangered; satellite tagging information available (other areas)	Allen and Angliss, 2012; Watwood et al., 2006
Conservation Importance	Humpback Whale	Endangered; much information available	Allen and Angliss, 2012
Conservation Importance	Steller sea lion	Endangered; Critical habitat	Allen and Angliss, 2012
Ecological Role	Northern fur seal	Highest population estimate (653,171)	Allen and Angliss, 2012
Birds- 4 total			
Conservation Importance	Steller's Eider	Federally Threatened. Coastal, nearshore, off shore. Feeds by shallow and deeper diving.	eBird 2012, BNA (Fredrickson 2001)
Conservation Importance	Spectacled Eider	Federally Threatened. Coastal, nearshore, off shore. Feeds by shallow and deeper diving.	eBird 2012, BNA (Petersen et al. 2000)
Ecological Role	Glaucous-winged Gull	Most common saltwater bird with habitat use that complements Conservation Importance Species and murrelet (near shore, surface and beach feeder). Coastal, near shore.	eBird 2012, BNA (Gilchrist 2001, Hayward and Verbeek 2008)
Ecological Role	Marbled Murrelet	Most common seabird with habitat use and behavior that complements Conservation Importance Species and gull (sometimes found further offshore, different foraging base and style).	eBird 2012, BNA (Nelson 1997)
Fish- 4 total			
Conservation Importance	Pacific herring	The SE Alaska DPS (Distinct Population Segment) is a candidate for listing. The DPS is defined as extending from the Dixon Entrance north to Cape Fairweather and Icy Point. There are no federally listed endangered or threatened species in this OCS Ecoregion.	NMFS 2012a
Fisheries Importance	Walleye Pollock	Based on 2000-2010 commercial landings for Alaska, this species had the highest landings by weight. Fisheries for walleye pollock occur in both the Gulf of	NMFS 2012c; ADF&G 2012a

Selection Criteria	Species	Selection Rationale	Reference
		Alaska and Bering Sea Aleutian Islands.	
Fisheries Importance	Pink salmon	Based on 2000-2010 commercial landings for Alaska, this species had the third highest landings by weight. This species also contributes substantially to sport angling.	NMFS 2012c; ADF&G 2012b
Ecological Role	Arrowtooth flounder	Arrowtooth flounder are currently the most abundant fish in the Gulf of Alaska and have substantial ecological importance at higher trophic levels in the Gulf of Alaska food web. This species has been identified as a significant food source for Steller sea lions and are known to be major predators of juvenile walleye pollock, an important commercial species.	AFSC 2012a
Invertebrates- 4 total			
Fisheries Importance	Golden king crab	Based on 2000-2010 commercial landings for Alaska, king crabs had the second highest landings by weight. The red king crab fishery was historically the top shellfish fishery in Alaska, but populations crashed in the 1980s and have remained depressed. Many commercial fishermen statewide have shifted to targeting golden king crabs, with most of the catch coming from the waters surrounding the Aleutian Islands.	NMFS 2012c; ADF&G 2012e,f
Fisheries Importance	Tanner crab	Based on 2000-2010 commercial landings for Alaska, this species had the fourth highest landings by weight. Tanner crabs are harvested in both the Bering sea and the Gulf of Alaska.	NMFS 2012c; ADF&G 2012g
Ecological Role	Euphausiid (*Thysanoessa inermis*)	*Thysanoessa inermis* is a common krill of the subarctic Pacific ocean. It is an important prey item for fish, birds, seals, and whales.	Arctic Ocean Biodiversity, 2012a; AFSC 2012b
Ecological Role	Baltic macoma clam	This species is widespread and a dominant member of the intertidal invertebrate community (range extends to 40 m). They are an important food source for coastal birds, fish, crabs (including king and tanner), and shrimp.	ADF&G 2012h

***Note:** In this application of the model, there was no allotment for conservation status invertebrates. However, there is a species of concern for this OCS Ecoregion. The pinto abalone is a species of concern from Sitka, AK south to Point Conception, CA (NMFS 2012b).

Table C-10: Species List and Rationale for Planning Areas 16, 17, 18, 19, 20, 21, 22, and 23 – East Bering Sea

Selection Criteria	Species	Selection Rationale	Reference
Mammals and Sea Turtles- 5 total			
Conservation Importance	Steller sea lion	Endangered; Critical habitat	Allen and Angliss, 2012
Conservation Importance	North Pacific Right Whale	Endangered; Critical Habitat	Allen and Angliss, 2012
Conservation Importance	Humpback Whale	Endangered; much information available	Allen and Angliss, 2012
Conservation Importance	Sperm whale	Endangered; most frequently sighted large cetacean near Aleutian Isl.	Allen and Angliss 2012
Ecological Role	Northern fur seal	Highest population estimate (653,171)	Allen and Angliss, 2012
Birds- 4 total			
Conservation Importance	Steller's Eider	Federally Threatened. Coastal, near shore, off shore. Feeds by shallow and deeper diving.	eBird 2012, BNA (Fredrickson 2001)
Conservation Importance	Short-tailed Albatross	Federally Endangered. Off shore, forages on water surface.	eBird 2012, Howell 2012
Ecological Role	Glaucous-winged Gull	Most common saltwater bird with habitat use that complements Conservation Importance Species and guillemot (near shore, surface and beach feeder). Coastal, near shore.	eBird 2012, BNA (Gilchrist 2001, (Hayward and Verbeek 2008)
Ecological Role	Pigeon Guillemot	Most common seabird with habitat use and behavior that complements Conservation Importance Species and gull (different foraging base and style, sometimes found further offshore).	eBird 2012, BNA (Ewins 1993)
Fish- 4 total			
Conservation Importance	N/A	There are no federally listed endangered or threatened species, candidate species, or species of concern in this OCS Ecoregion.	NMFS 2012a
Fisheries Importance	Walleye Pollock	Based on 2000-2010 commercial landings for Alaska, this species had the highest landings by weight. Fisheries for walleye pollock occur in both the Gulf of Alaska and Bering Sea Aleutian Islands.	NMFS 2012c
Fisheries Importance	Pink salmon	Based on 2000-2010 commercial landings for Alaska, this species had the third highest landings by weight. This species also contributes substantially to sport	NMFS 2012c; ADF&G 2012b

Selection Criteria	Species	Selection Rationale	Reference
		angling.	
Ecological Role	Atka mackerel	Atka mackerel are a key prey source for marine fishes, birds, and marine mammals such as the Steller sea lion. This species is abundant in the central and western Aleutian archipelago. It is the 6th highest fish species for commercial landings in Alaska (2000-2010).	ADF&G 2012c; NMFS 2012c
Invertebrates- 4 total			
Fisheries Importance	Golden king crab	Based on 2000-2010 commercial landings for Alaska, king crabs had the second highest landings by weight. The red king crab fishery was historically the top shellfish fishery in Alaska, but populations crashed in the 1980s and have remained depressed. Many commercial fishermen statewide have shifted to targeting golden king crabs, with most of the catch coming from the waters surrounding the Aleutian Islands.	NMFS 2012c; ADF&G 2012e,f
Fisheries Importance	Snow crab	Based on 2000-2010 commercial landings for Alaska, this species had the highest landings by weight. Snow crabs are harvested mainly in the Bering Sea.	NMFS 2012c; ADF&G 2012g
Ecological Role	Euphausiid (*Thysanoessa inermis*)	*Thysanoessa inermis* is a common krill of the subarctic Pacific ocean. It is an important prey item for fish, birds, seals, and whales.	Arctic Ocean Biodiversity, 2012a
Ecological Role	Baltic macoma clam	This species is widespread and a dominant member of the intertidal invertebrate community (range extends to 40 m). They are an important food source for coastal birds, fish, crabs (including king and tanner), and shrimp.	ADF&G 2012h

Table C-11: Species List and Rationale for Planning Areas 24, 25, and 26 – Chukchi and Beaufort Seas

Selection Criteria	Species	Selection Rationale	Reference
Mammals and Sea Turtles- 5 total			
Conservation Importance	Polar bear	Threatened; Critical habitat	Allen and Angliss, 2012
Conservation Importance	Bowhead Whale	Endangered; much available information	Allen and Angliss, 2012
Conservation Importance	Pacific Walrus	Candidate	Allen and Angliss, 2012
Conservation Importance	Ringed Seal	Proposed threatened	Allen and Angliss, 2012
Ecological Role	Beluga	Occurs in both Chukchi and Beaufort Seas; much information available	Allen and Angliss, 2012
Birds- 4 total			
Conservation Importance	Steller's Eider	Federally Threatened. Coastal, near shore, off shore. Feeds by shallow and deeper diving.	eBird 2012, BNA (Fredrickson 2001)
Conservation Importance	Spectacled Eider	Federally Threatened. Coastal, near shore, off shore. Feeds by shallow and deeper diving.	eBird 2012, BNA (Petersen et al. 2000)
Ecological Role	Glaucous Gull	Most common saltwater bird with habitat use that complements Conservation Importance Species and phalarope (near shore, surface and beach feeder). Coastal, near shore.	eBird 2012, BNA (Gilchrist 2001, (Hayward and Verbeek 2008)
Ecological Role	Red-necked Phalarope	Most common seabird with habitat use and behavior that complements Conservation Importance Species and gull (different foraging base and style, found further offshore).	eBird 2012, BNA (Rubega et al. 2000)
Fish- 4 total			
Conservation Importance	N/A	There are no federally listed endangered or threatened species, candidate species, or species of concern in this OCS Ecoregion.	NMFS 2012a
Fisheries Importance	Arctic cisco	No commercial fishing occurs in the Arctic except for several small state-managed species. One of these small fisheries is for Arctic cisco. This species is the most important commercial and subsistence fish species in this OCS Ecoregion.	ADF&G 2012d; NPFMC 2009
Fisheries	Dolly varden	No commercial fishing occurs in the Arctic except for	ADF&G

Selection Criteria	Species	Selection Rationale	Reference
Importance		several small state-managed species. This is a popular sport and subsistence fish throughout their range. It is a very important species for the people of northwestern Alaska.	2012i; NPFMC 2009
Ecological Role	Arctic cod	This species is one of the most abundant fish in the OCS Ecoregion and a key component of the food web. They are a major prey source for whales, birds, seals, and other fish; for several species, Arctic cod makes up the majority of their diet.	NPFMC 2009
Invertebrates- 4 total			
Fisheries Importance	Snow crab	No commercial fishing occurs in the Arctic except for several small state-managed fish species. However, this species has the highest exploitable biomass in the Arctic OCS Ecoregion and are fished for subsistence purposes in the southeastern Chukchi Sea. It is also the only invertebrate species with essential fish habitat (EFH) designated in the Arctic.	NPFMC 2009; Normandeau Associates, 2012
Fisheries Importance	Blue king crab	No commercial fishing occurs in the Arctic except for several small state-managed fish species. King crabs (*Paralithodes* spp.) are fished for subsistence purposes in the southeastern Chukchi Sea, but the species is not identified. We selected blue king crab to represent this species group, as its range extends farther north than the red king crab.	NPFMC 2009; Normandeau Associates, 2012
Ecological Role	Euphausiid (*Thysanoessa raschii*)	*Thysanoessa raschii* is the most widespread Arctic krill and are an important prey item for fish, birds, seals, and whales.	Arctic Ocean Biodiversity, 2012b
Ecological Role	Baltic macoma clam	This species is widespread and a dominant member of the intertidal invertebrate community (range extends to 40 m). They are an important pre item for coastal birds, fish, crabs (including king and tanner), and shrimp.	ADF&G 2012h

Table C-12: Habitat List and Rationale for Planning Areas 1 and 2 – Northeastern U.S. Continental Shelf

Selection Criteria	Habitat	Selection Rationale	Reference
		Estuarine	
Benthic	Aquatic Vascular Vegetation (AVV)	High degree of primary and secondary productivity per unit area. Important forage and nursery habitat to numerous species of fish and invertebrates. Three species present in NECS; eelgrass, widgeon grass, and Cuban shoalgrass. Eelgrass dominates and Cuban shoalgrass occurs as far north as NC.	Thayer et al. 1984; Kaplan ed. 2011
Water Column	Open Water	High degree of primary productivity per unit area. EFH to numerous species of fish and invertebrates.	MAFMC 1978 a,b,c
		Marine – Nearshore/Offshore	
Benthic	Banks	Features such as Georges Bank, Stellwagen Bank, Nantucket Shoals represent ecologically significant and productive areas with the NECS.	Kaplan ed. 2011
	Submarine Canyons	There are over 70 submarine canyons within the NECS OCS Ecoregion. Major geologic structures such as the Hudson Canyon, Washington Canyon, Baltimore Canyon, and Norfolk Canyon. They support high abundances and diversity of marine fauna. Exposed hard substrate provide habitat for sessile organisms.	Kaplan ed. 2011
Pelagic	Surface/Photic Zone	High degree of primary productivity per unit area. EFH to numerous species of fish and invertebrates.	MAFMC FMPs
		Marine – Oceanic	
Benthic	Deepwater Coral	High biodiversity. Important habitat for commercially valuable species of fish and invertebrates.	Lumsden et al. 2007, 2009
	Slope	The continental shelf/slope break area, from the 100-meter to the 400-meter isobath, has been identified as a highly productive zone, supporting high densities of *Illex* and *Loligo* squid, which are commercially valuable and also are important prey of many marine species. Also important to loggerhead sea turtles and many species of fish and cetaceans	Kaplan ed. 2011

Table C-13: Habitat List and Rationale for Planning Areas 3 and 4 – Southeastern U.S. Continental Shelf

Selection Criteria	Habitat	Selection Rationale	Reference
		Estuarine	
Benthic	Aquatic Vascular Vegetation (AVV)	High degree of primary and secondary productivity per unit area. Present in NC and FL estuarine waters. Important forage and nursery habitat to numerous species of fish and invertebrates.	SAFMC 1998
Water Column	Open Water	High degree of primary productivity per unit area. EFH to numerous species of fish and invertebrates.	SAFMC 1998
		Marine – Nearshore/Offshore	
Benthic	Shallow/Mesophotic Coral	High biodiversity. High primary and secondary productivity. Important EFH to numerous species of fish and invertebrates.	Gulf of Mexico and SAFMCs 1982
	Worm Substrate	Reefs extend for hundreds of kilometers along SE coast of FL. High biodiversity. High primary and secondary productivity. Important EFH to numerous species of fish and invertebrates.	CSA International 2009; Zale and Memfield 1982.
Water Column	Algal Rafts (*Sargassum*)	Supports a diverse assemblage of organisms including at least 145 species of invertebrates, over 100 species of fish, 5 sea turtle species, and numerous marine birds. Fish abundance positively correlated to *Sargassum* biomass.	SAFMC 2002
		Marine – Oceanic	
Benthic	Deepwater Coral	High biodiversity. Important habitat for commercially valuable species of fish and invertebrates.	Lumsden et al. 2007, 2009
	Fine Unconsolidated Substrate (FUS)	Sediment type is a major factor in determining the associated fish and invertebrate community. FUS important habitat for numerous fish and invertebrate species.	SAFMC 1998

Table C-14: Habitat List and Rationale for Planning Area 5 – Eastern Gulf of Mexico

Selection Criteria	Habitat	Selection Rationale	Reference
Estuarine			
Benthic	Mollusk Reef	Oyster reefs are highly productive and provide structural complexity in soft sediment. More than 300 species have been documented on intertidal and subtidal oyster reefs. Oyster reefs serve as fish habitat.	GMFMC 2004
Water Column	Open Water	High degree of primary productivity per unit area. EFH to numerous species of fish and invertebrates.	GMFMC 2004
Marine – Nearshore/Offshore			
Benthic	Aquatic Vascular Vegetation (AVV)	High degree of primary and secondary productivity per unit area. Extension seagrass in nearshore areas of FL Big Bend area off west coast covering approx. 3,000 sq km. Important forage and nursery habitat to numerous species of fish and invertebrates.	Handley et al. 2007
	Live Hard Bottoms	Extensive emergent substrate that comprises a high percentage of the west Florida shelf supports the growth of biological assemblages such as sea fans, sea whips, hydroids, anemones, ascidians, sponges, bryozoans, or corals living upon and attached to naturally occurring hard or rocky formations with rough, broken, or smooth topography. Includes Pinnacle Trend in Also provides habitat for sea turtles and numerous fish species.	GMFMC 1998; Thompson et al. 1999
Water Column	Algal Rafts (*Sargassum*)	Supports a diverse assemblage of organisms including at least 145 species of invertebrates, over 100 species of fish, 5 sea turtle species, and numerous marine birds. Fish abundance positively correlated to *Sargassum* biomass.	SAFMC 2002
Marine – Oceanic			
Benthic	Deepwater Coral	Deepwater corals provide habitat for diverse communities of organisms, including commercially important fisheries species. In addition, macrofauna and megafauna may occur in numbers that are orders of magnitude higher in deepwater coral habitats than on the surrounding seafloor.	CSA International 2007; Lumsden et al. 2007, 2009
	Seeps	Found commonly across the Gulf of Mexico's northern continental slope. Two styles of	MacDonald ed 2002; Lessard-

Selection Criteria	Habitat	Selection Rationale	Reference
		seeps – sediment diffusion and brine pooling. Long-lived communities.	Pilon et al. 2010

Table C-15: Habitat List and Rationale for Planning Areas 6 and 7 – Western Gulf of Mexico

Selection Criteria	Habitat	Selection Rationale	Reference
Estuarine			
Benthic	Aquatic Vascular Vegetation (AVV)	Seagrass-dominated communities support higher biodiversity and production than any other biotic community along the Texas coast. Approximately 220,00 acres in TX and less than 1,000 acres in LA	Handley et al. 2007
Water Column	Open Water	High degree of primary productivity per unit area. EFH to numerous species of fish and invertebrates.	GMFMC 2004
Marine – Nearshore/Offshore			
Benthic	Banks	Important areas of biodiversity and productivity. Over 100 charted calcareous banks in NW Gulf of Mexico. Prominent features include East and West Flower Garden Banks located on the outer edge of the continental shelf southeast of Galveston, TX.	Deslarzes (ed.) 1998
	Fine Unconsolidated Substrate (FUS)	Sediment type is a major factor in determining the associated fish and invertebrate community. Shrimp distribution closely matches sediment distribution. Example, White shrimp and brown shrimp occupy the terrigenous muds, while pink shrimp occur on calcareous sediments.	GMFMC 2004
Pelagic	Surface/Photic Zone	High degree of primary productivity per unit area. EFH to numerous species of fish and invertebrates.	GMFMC 2004
Marine – Oceanic			
Benthic	Deepwater Coral	Deepwater corals provide habitat for diverse communities of organisms, including commercially important fisheries species. In addition, macrofauna and megafauna may occur in numbers that are orders of magnitude higher in deepwater coral habitats than on the surrounding seafloor.	CSA International 2007; Lumsden et al. 2007, 2009
	Seeps	Found commonly across the Gulf of Mexico's northern continental slope. Two styles of seeps – sediment diffusion and brine pooling. Long-lived communities.	MacDonald ed. 2002; Lessard-Pilon et al. 2010

Table C-16: Habitat List and Rationale for Planning Areas 8, 9, and 10 – California Current

Selection Criteria	Habitat	Selection Rationale	Reference
Estuarine			
Benthic	Aquatic Vascular Vegetation (AVV)	High degree of primary and secondary productivity per unit area. Present in estuarine waters. Seagrass species include eelgrass species (*Zostera* spp.), widgeongrass (*Ruppia maritima*), and surfgrass (*Phyllospadix* spp.). Important forage and nursery habitat to numerous species of fish and invertebrates.	Kaplan et al. (eds) 2010
Water Column	Open Water	High degree of primary productivity per unit area. EFH to numerous species of fish and invertebrates.	Kaplan et al. (eds) 2010; Pacific Fishery Management Council 2011
Marine – Nearshore/Offshore			
Benthic	Fine Unconsolidated Substrate (FUS)	FUS predominant in ecoregion. Important habitat for invertebrate and fish. EFH to numerous species of fish and invertebrates.	Lissner (ed.) 1989
	Submarine Canyons	Numerous submarine canyons within Ecoregion 5 including; Monterey, Hueneme, Mugu, LaJolla, and Scripps Canyons. Because submarine canyons extend from shallow waters to the deep sea, they support high abundances and diversity of marine fauna. Exposed hard substrate provide habitat for sessile organisms.	Crowell 1952
Pelagic	Algal Rafts (Kelp)	Kelp stands provide nurseries, feeding grounds, and shelter to a variety of groundfish species and their prey. Giant kelp communities are highly productive relative to other habitats	Pacific Fishery Management Council 2011
Marine – Oceanic			
Benthic	Deepwater Coral	High biodiversity. Important habitat for commercially valuable species of fish and invertebrates.	Lumsden et al. 2007, 2009
	Seamounts	Important fish habitat. Create complex current patterns. Have relatively high biodiversity and up to a third of species occurring on these features may be endemic.	de Forges et al. 2000

Table C-17: Habitat List and Rationale for Planning Area 11 – Washington/Oregon

Selection Criteria	Habitat	Selection Rationale	Reference
Estuarine			
Benthic	Aquatic Vascular Vegetation (AVV)	High degree of primary and secondary productivity per unit area. Eelgrass dominant species present in estuarine waters. Important forage and nursery habitat to numerous species of fish and invertebrates.	Phillips and Watson 1984; Larkum et al. 2006
Water Column	Open Water	High degree of primary productivity per unit area. EFH to numerous species of fish and invertebrates.	Pacific Fishery Management Council 2011
Marine – Nearshore/Offshore			
Benthic	Fine Unconsolidated Substrate (FUS)	FUS predominant in Ecoregion. Important habitat for invertebrate and fish. EFH to numerous species of fish and invertebrates.	Pacific Fishery Management Council 2011
	Boulder	Important habitat for groundfish and invertebrates.	Pacific Fishery Management Council 2011
Pelagic	Algal Rafts (Kelp)	Kelp stands provide nurseries, feeding grounds, and shelter to a variety of groundfish species and their prey. Giant kelp communities are highly productive relative to other habitats	Kaplna et al. (eds) 2010; Pacific Fishery Management Council 2011
Marine – Oceanic			
Benthic	Deepwater Coral	High biodiversity. Important habitat for commercially valuable species of fish and invertebrates.	Lumsden et al. 2007, 2009
	Seamounts	Important fish habitat. Create complex current patterns. Have relatively high biodiversity and up to a third of species occurring on these features may be endemic.	de Forges et al. 2000

Table C-18: Habitat List and Rationale for Planning Areas 12, 13, 14, and 15 – Gulf of Alaska

Selection Criteria	Habitat	Selection Rationale	Reference
Estuarine			
Benthic	Aquatic Vascular Vegetation (AVV)	High degree of primary and secondary productivity per unit area. Eelgrass present in estuarine waters. Important forage and nursery habitat to numerous species of fish and invertebrates.	McRoy 1968; Phillips and Watson 1984; Johnson et al 2003
Water Column	Coastal Band	High degree of primary productivity per unit area. EFH to numerous species of fish and invertebrates.	
Marine – Nearshore/Offshore			
Benthic	Cobble/Rock	Important habitat and EFH to numerous groundfish such as Pacific cod and variety of rockfish species.	North Pacific Fishery Management Council 2012a
	Fine Unconsolidated Substrate (FUS)	Unvegetated, unconsolidated fine sediment is important habitat for groundfish such as Walleye Pollock, Pacific cod and a variety of species of sole and flounder.	North Pacific Fishery Management Council 2012a
Pelagic	Algal Rafts (Kelp)	Kelp stands provide nurseries, feeding grounds, and shelter to a variety of fish species and their prey. Kelp communities are highly productive relative to other habitats	Johnson et al. 2003
Marine – Oceanic			
Benthic	Deepwater Coral	High biodiversity. Important habitat for commercially valuable species of fish and invertebrates.	Lumsden et al. 2007, 2009; Stone and Shotwell 2007
	Seamounts	Important fish and invertebrate habitat. Create complex current patterns. Have relatively high biodiversity and up to a third of species occurring on these features may be endemic.	Uchida et al (eds) 1986; Hoff & Stevens 2005

Table C-19: Habitat List and Rationale for Planning Areas 16, 17, 18, 19, 20, 21, 22, and 23 – East Bering Sea

Selection Criteria	Habitat	Selection Rationale	Reference
Estuarine			
Benthic	Aquatic Vascular Vegetation (AVV)	High degree of primary and secondary productivity per unit area. Eelgrass present in estuarine waters. Important forage and nursery habitat to numerous species of fish and invertebrates.	McRoy 1968; Winfree 2005
Water Column	Coastal Band	High degree of primary productivity per unit area. EFH to numerous species of fish and invertebrates.	
Marine – Nearshore/Offshore			
Benthic	Fine Unconsolidated Substrate (FUS)	Unvegetated, unconsolidated fine sediment is primary bottom habitat and important habitat for fish and invertebrates.	Smith and McConnaughey 1999; McConnaughey and Smith 2000
	Shelf Break	Dominant driver of primary productivity in EBS.	
Pelagic	Pack Ice	A special feature of the EBS is the pack ice that covers most of its eastern and northern continental shelf during winter and spring.	North Pacific Fishery Management Council 2012b
Marine – Oceanic			
Benthic	Deepwater Coral	High biodiversity. Important habitat for commercially valuable species of fish and invertebrates.	Lumsden et al. 2007, 2009; Stone and Shotwell 2007
	Ridge/Rock	Ridges (e.g., Bowers and Zhemchug) and rocky habitat rare in Bering Sea and important habitat to numerous fish and invertebrates.	Rooper and Hoff 2008; North Pacific Fishery Management Council 2012b

Table C-20: Habitat List and Rationale for Planning Areas 24, 25, and 26 – Chukchi and Beaufort Seas

Selection Criteria	Habitat	Selection Rationale	Reference
Estuarine			
Benthic	Benthic Macroalgae	Provides high degree of primary productivity to region in winter. Kelp contributes to the energy base (primary productivity) in the benthic-pelagic food web of the Beaufort Sea. Kelp species photosynthesizes during the short Arctic summer and undertakes its yearly growth under ice, in the dark, during the long Arctic winter. Habitat and food source for numerous fish and invertebrates.	Newberry 1998
Water Column	Coastal Band	Coastal lagoons along the Beaufort Sea are biologically important features, particularly in summer, because of an estuarine band of warm and brackish water which increases productivity compared to the adjacent marine zone. Water temperatures and salinity range from 5 to 10ºC and 10-25‰ in summer, compared to the adjacent marine zone, where temperature and salinity range from -1 to 3ºC and 27-32‰.	Coastal Response Research Center. 2010
Marine – Nearshore/Offshore			
Benthic	Boulder Fields	Provide unique surfaces in region. Only known hard bottom habitat. Example, Boulder Patch contains numerous cobbles and boulders that provide substrate for attachment for many invertebrates, several species of red and brown algae, and one green alga	MMS 1996; Konar 2006
	Fine Unconsolidated Substrate (FUS)	Unvegetated, unconsolidated fine sediment is primary bottom habitat and important source of prey for fish and invertebrates.	North Pacific Fishery Management Council 2009; Smith 2011
Pelagic	Ice	Sea ice is a key ecological characteristic of the Chukchi and Beaufort Seas. The life history activities of many species (e.g., Pacific walrus, polar bear, ringed seal, spotted seal, bearded seal, ribbon seal) are closely linked to the location and extent of sea ice.	Coastal Response Research Center. 2010
Marine – Oceanic			
Benthic	Fine Unconsolidated	Unvegetated, unconsolidated fine sediment is primary bottom habitat and important source	Smith 2011

Selection Criteria	Habitat	Selection Rationale	Reference
	Substrate (FUS)	of prey for fish and invertebrates.	
	Deepwater Coral	High biodiversity. Important habitat for commercially valuable species of fish and invertebrates.	Lumsden et al. 2007, 2009; Stone and Shotwell 2007

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APPENDIX D: COMPREHENSIVE LIST OF IMPACTS FROM BOEM ACTIVITIES

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Table D-1: Oil and Gas Impacts

Project Phase	**Impact-causing Factors for Oil and Gas**
Seismic Surveys	Sound/Noise
	EMF
	Ship traffic
	Helicopter Traffic (birds)
	Marine debris (Styrofoam, paper plastic, wood, metal, etc.)
Exploration and Delineation Phase (Temporary) Drillship, Semi-submersible, Shallow-water (<100m) Jackup	Habitat disturbance
	Habitat displacement
	Sound/Noise
	Ship traffic
	Drill muds, cuttings, and fluids
	Produced water
	Marine debris (Styrofoam, paper plastic, wood, metal, etc.)
	H_2S Subsurface Leak
	Collisions, entanglement with sub-surface structures
	Collisions with above-surface structures
	Artificial light
	Dispersants
	Accidental Chemical Spills
	Oil Spills
	Seafloor Blowouts
	Anchoring
	Helicopter Traffic (birds)
	Deck Drainage
	Land-based Support Facilities
Development and Production Phase (Permanent) Subsea (300-1,200 m), Fixed (0-450m), Compliant Tower (300-900m), FSPO (0-1,200m), Tension Leg (600-3,050m), All with Seafloor/Subsea Pipelines and Flowlines	Habitat disturbance
	Habitat displacement
	Sound/Noise
	EMF
	Ship traffic

Project Phase	Impact-causing Factors for Oil and Gas
	Drill muds, cuttings, and fluids
	Produced water
	Marine debris (Styrofoam, paper plastic, wood, metal, etc.)
	H_2S Subsurface Leak
	Collisions, entanglement with sub-surface structures
	Collisions with above-surface structures
	Artificial light
	Dispersants
	Accidental Chemical Spills
	Oil Spills
	Seafloor Blowouts
	Anchoring
	Helicopter Traffic (birds)
	Deck Drainage
	Land-based Support Facilities
Structure Removal	Explosives
	Mechanical Cutting
	Habitat disturbance
	Habitat displacement
	Ship Traffic
	Marine debris (Styrofoam, paper plastic, wood, metal, etc.)
	Anchoring
	Helicopter Traffic (birds)

Table D-2: Offshore Alternative Energy Impacts

Project Phase	**Impact-causing Factors for Offshore Alternative Energy**
Pre-construction (exploration, site evaluation, technology testing)	habitat disturbance
	habitat displacement
	sound/noise
	EMF
	ship traffic
	accidental spills
	collisions, entanglement with sub-surface structures
	collisions with above-surface structures
	artificial light
Construction	habitat disturbance
	habitat displacement
	sound/noise
	EMF
	ship traffic
	accidental spills
	collisions, entanglement with sub-surface structures
	collisions with above-surface structures
	artificial light
Operation and maintenance	habitat disturbance
	habitat displacement
	sound/noise
	EMF
	ship traffic
	accidental spills
	collisions, entanglement with sub-surface structures
	collisions with above-surface structures
	artificial light
Decommissioning	habitat disturbance
	habitat displacement
	sound/noise
	EMF

Project Phase	Impact-causing Factors for Offshore Alternative Energy
	ship traffic
	accidental spills
	collisions, entanglement with sub-surface structures
	collisions with above-surface structures

Table D-3: Parsed List of Impact Factors Assessed in RESA Model (all project phases collapsed into respective impact factors)

Impact	Impact Factor
Oil and Gas	Accidental Spill
	Artificial Light
	Collisions with Above Surface Structures
	Habitat Disturbance
	Sound/Noise
	Vessel Strikes
	Oil Spill
Renewable Energy	Accidental Spill
	Artificial Light
	Collisions with Above Surface Structures
	Habitat Disturbance
	Sound/Noise
	Vessel Strikes

The follow sections describe modeled impact factor definitions, modeling characteristics and modeling ranks for oil and gas, and renewable energyactivities.

D.1 OIL AND GAS IMPACT FACTORS

Three phases of impact producing factors are included in the Oil and Gas portion of the RESA (the following descriptions are primarily drawn from the BOEM PEIS):

Exploration - During exploration, typical activities include the conduct of geophysical seismic surveys and possibly the drilling of exploration wells.

Development- Once exploration has confirmed the presence of a commercially viable reservoir, the next phase of oil and gas development is the construction of the production platform and drilling of production wells. Temporarily abandoned exploration wells may also be completed for production.

Operation- Following completion of the production wells and platform, the facilities are operated to extract the hydrocarbon resource and transport it to onshore processing facilities. *Decommissioning* activities are not included in this analysis. This is due to the wide range of decommissioning activities which occur (explosive vs. non-explosive) and the uncertain timeframe in which decommissioning activities occur.
All portions of exploration, development and operation are considered jointly when assessing species and habitat sensitivity to each impact factor.

D.1.1 Impact Factor: Accidental Spills

Definition: A variety of accidental events or spills may be expected to occur during OCS oil and gas exploration and development activities. Accidental Spills entail small oil and chemical spills not resulting from routine operations. Accidental Spills may be associated with production accidents, transportation failures (e.g., tankers, storage facilities), and low-level releases from platforms (BOEM 2012). Other spill factors, such as loss of well control and transportation failures related to seafloor pipeline failures, are included under the Oil Spill impact factor. Additionally, Accidental Spills include the release of solid waste materials, such as plastic containers, nylon rope and plastic bags. Accidental discharge of sanitary and domestics wastes is also included within this impact factor. During normal operations, ship and platform activities generate a variety of solid waste materials, such as plastic containers, nylon rope and fasteners, and plastic bags. The accidental release of such solid waste materials could affect marine mammals, sea turtles, and birds. While sanitary and domestic wastes produced in ships and platforms are routinely processed through onsite waste treatment facilities, the accidental discharge of such releases could affect local water quality and biota. Ships supporting platform activities may accidentally collide with MODUS or platforms, releasing diesel fuel, which could affect water quality and biota. Oil and condensate spills may also occur directly from platforms, drilling ships, and support vessels. Depending on the phase of oil and gas development and the location, magnitude, and duration of a spill, natural resources that may be affected include marine mammals, marine and coastal birds, sea turtles, fish, benthic and pelagic invertebrates, water quality, marine and coastal habitats, and areas of special concern (such as marine parks and protected areas).

Areal Range: *-3-3700m*
Impact Areal Range minimum is assumed to be a small distance above mean high water level at the shoreline (-3 m) for accidental spills. This assumption is based on the potential that accidental spills could potentially occur right up to the shoreline. No evidence has been presented to the contrary. Impact Areal Range maximum is based on the maximum reported depth at which Oil and Gas drilling could occur. A report by Chevron (Chevron 2010) notes that current drillship technology allows oil development down to depths of 3,700m. Impact areal range maximum (distance from shore) was calculated based on the distance from shore the maximum bathymetric contour occurs at for each geographic region (average). Worldwide

bathymetry data was obtained through the NOAA ETOPO1 Global Relief Model, a global 1 arc-minute model that integrates both land topography and ocean bathymetry. The data, in the form of a float file, were imported into ArcGIS and the "Contour List" tool within the Spatial Analyst Toolbox Extension was used to extract a bathymetry contours of 3,700 m. Distances between the coastline and the contours were measured in each of the planning regions using the "Distance' tool. However, the contours are not entirely consistent within the planning regions; therefore, these distances are averages. This methodology was used to determine maximum areal extents for all impact factors and is not repeated in subsequent sections.

Probable Areal Range: *0-1500m*

Depth Range: *0-100m*
Accidental Spills are assumed to potentially occur at the surface or near-surface of the water column. A value of 100m depth is used to define the maximum depth at which this impact causing factor could occur. Larger/deeper subsurface oil spills are included under the Oil Spill impact factor.

Probable Depth Range: *0-100m*

Impact Scale: *Small*
Accidental spills, by definition, entail impacts spanning up to a few square kilometers.

Impact Duration: *Short Term*
Accidental Spills fall into the Short-Term category: a short-term event whose effects are relaxed almost immediately (minutes to days) (pulse effect).

Current Level of Development: Current development is based on general public information regarding the current number of oil platforms/rigs in each planning area/broad OCS region.

D.1.2 Impact Factor: Artificial Light

Definition: Artificial Light refers to all light emanating from the exploration, construction and operation of oil and gas activities including both platforms and ships. Detrimental effects of artificial light may include increased chances of collision, skewed migratory pathways, and unnatural accumulation of species to non-preferable habitats.

Areal Range: *-3-3700m*
Impact Areal Range minimum is assumed to be the shoreline (0 m) for all impact factors. This assumption is based in the potential that the two impacts (Oil and Gas and Renewable Energy) could potentially occur right up to the shoreline. No evidence has been presented to the contrary. Impact Areal Range maximum is based on the maximum reported depth at which Oil and Gas drilling could occur.

Probable Areal Range: *25-1500m*

Depth Range: *-100-5m*

Minimum depth range for Artificial Light represents the maximum height above the waterline at which artificial light may adversely affect biota. A height of 100m has been selected; many large oil platforms may reach up to 70 m or more above the water surface (e.g., Petronius Platform) and the height of lighting structures and the distance traveled by artificial light may extend the visible effects of the artificial light to around 100m. The maximum depth of artificial light is given as 0 m. Complete light attenuation is assumed to occur at the water surface.

Probable Depth Range: *-100-5m*

Impact Scale: *Moderate*

Impact Duration: *Permanent*
Given the extremely long life span of oil rigs (approximately 30 years) and the persistent use of artificial light on rigs; artificial light is designated as a permanent impact factor.

Current Level of Development: Current development is based on general public information regarding the current number of oil platforms/rigs in each planning area/broad OCS region.

D.1.3 Impact Factor: Collisions with Above-Surface Structures

Definition: This impact factor is defined as the detrimental effects of above water surface structures on biota unaccustomed to the BOEM regulated activity structures on the outer continental shelf, resulting in harmful collisions with these structures.

Areal Range: *0-3700m*
Impact Areal Range minimum is assumed to be the shoreline (0 m) for all impact factors. This assumption is based in the potential that the two impacts (Oil and Gas and Renewable Energy) could potentially occur right up to the shoreline. No evidence has been presented to the contrary. Impact Areal Range maximum is based on the maximum reported depth at which Oil and Gas drilling could occur.

Probable Areal Range: *25-1500m*

Depth Range: *-100-0m*
Minimum depth range for Collisions represents the maximum height above the waterline at which oil rig platforms may adversely affect biota. A height of 100m has been selected; many large oil platforms may reach up to 70 m or more above the water surface (e.g., Petronius Platform). The maximum depth of collisions is given as 0 m (water surface).

Probable Depth Range: *-100-0m*

Impact Scale: *Site-Specific*

Impact Duration: *Permanent*
Given the extremely long life span of oil rigs (approximately 30 years) the Collisions with Above Surface Structures impact factor is designated as a Permanent impact factor.

Current Level of Development: Current development is based on general public information regarding the current number of oil platforms/rigs in each planning area/broad OCS region.

D.1.4 Impact Factor: Habitat Disturbance

Definition: Habitat disturbance refers to general benthic habitat disturbance and displacement due to exploratory drilling and infrastructure placement (e.g., pipeline trenching and placement and platform placement).

Areal Range: *0-3700m*
Impact Areal Range minimum is assumed to be the shoreline (0 m) for all impact factors. This assumption is based in the potential that the two impacts (Oil and Gas and Renewable Energy) could potentially occur right up to the shoreline. No evidence has been presented to the contrary. Impact Areal Range maximum is based on the maximum reported depth at which Oil and Gas drilling could occur.

Probable Areal Range: *25-1500m*

Depth Range: *0-3700m*
Habitat disturbance may occur at any depth where offshore drilling occurs.

Probable Depth Range: *25-1500m*

Impact Scale: *Site-Specific*

Impact Duration: *Permanent*
Given the extremely long life span of oil rigs (approximately 30 years) as well as the potential for explosive decommissioning and the "rigs to reef" (RTR) program, habitat disturbance is considered a Permanent impact factor.

Current Level of Development: Current development is based on general public information regarding the current number of oil platforms/rigs in each planning area/broad OCS region.

D.1.5 Impact Factor: Sound/Noise

Definition: The Sound/Noise impact factor refers to the artificial sound and noise created by oil and gas ship and rig exploration (including seismic surveys), construction, and operation. The main drivers of sound and noise include: seismic surveys, ship traffic noise, construction of offshore facilities and pipelines, and rig operation.

Areal Range: *-3-3700m*
Impact Areal Range minimum is assumed to be the shoreline (0 m) for all impact factors. This assumption is based in the potential that the two impacts (Oil and Gas and Renewable Energy) could potentially occur right up to the shoreline. No evidence has been presented to the contrary.

Impact Areal Range maximum is based on the maximum reported depth at which Oil and Gas drilling could occur.

Probable Areal Range: *25-1500m*

Depth Range: *0-100m*
The depth range of the Sound/Noise impact factor is deemed to be from 0-100 m. Though construction of oil rigs will result in artificially elevated sound at depths greater than this, the source levels from drilling are relatively low (154 dB and below, as cited by Greene [1986] in Richardson et al. [1995]), below the level B (behavioral) harassment threshold of 160 dB (set by NMFS). Thus only surface related sound/noise is considered in this analysis. The choice of 100m depth is fairly arbitrary and should be better defended or amended.

Probable Depth Range: *0-100m*

Impact Scale: *Moderate*

Impact Duration: *Moderate-Term*
Though operation noise is fairly continuous due to ship traffic and general background noise, the more seriously detrimental sound/noise is due to short term events such as seismic surveys. Sound/noise has been assessed as a short-term impact factor accordingly.

Current Level of Development: Current development is based on general public information regarding the current number of oil platforms/rigs in each planning area/broad OCS region.

D.1.6 Impact Factor: Vessel Strikes

Definition: Service vessel traffic during construction and operation of renewable energy projects is forecast to be extremely high (e.g., up to 600 vessels per week, see BOEM 2012). There have been documented reports of cetaceans being struck by ships in the oceans throughout the world (Laist et al. 2001; Jensen and Silber 2004; Glass et al. 2008). Analyses by Vanderlaan and Taggart (2007) provides evidence that as vessel speeds fall below 15 knots, there is a substantial decrease in the probability of a vessel strike to prove lethal to a large whale. Collisions with vessels greater than 80 m in length are usually either lethal or result in severe injuries (Laist et al. 2001). In addition, a majority of ship strikes seemed to occur over or near the continental shelf. Collisions with vessels can cause major wounds on marine mammals and/or be fatal. Debilitating injuries may have negative effects on a population through impairment of reproductive output (MMS 2003).

Areal Range: *0-3700 m*

Probable Areal Range: *0-1500m*

Depth Range: *0-15m*

Probable Depth Range: *0-10m*

Impact Scale: *Moderate*

Impact Duration: *Chronic*

Current Level of Development: Current development is based on general public information regarding the current number of oil platforms/rigs in each planning area/broad OCS region.

D.1.7 Impact Factor: Oil Spill

Definition: Oil Spills refer to the release of oil due to serious operational failure of an oil rig, wellhead or pipeline. The magnitude of an oil spill will in actuality depend on the location, timing and volume of the spill; the environmental setting of the spill; and the species exposed to the spill. For the purposes of this model we will assume an oil spill as significant as the Deepwater Horizon blowout, which could occur in any of the environmental settings of a planning area/broad OCS region and will interact with all of the biota of the given area. Depending on the phase of oil and gas development and the location, magnitude, and duration of a spill, natural resources that may be affected include marine mammals, marine and coastal birds, sea turtles, fish, benthic and pelagic invertebrates, water quality, marine and coastal habitats, and areas of special concern (such as marine parks and protected areas).

Areal Range: Impact Areal Range minimum is assumed to be the shoreline (0 m) for all impact factors. This assumption is based in the potential that the two impacts (Oil and Gas and Renewable Energy) could potentially occur right up to the shoreline. No evidence has been presented to the contrary. The maximum Areal Range of Oil Spills is assumed to be the offshore limits of each respective planning area/ broad OCS region. Large oil spills are assumed to be driven by local currents and wind direction which may potentially force the spills directly offshore, resulting in effects of oil spills out to the maximum extent of an area. This maximum extent of a planning area/broad OCS region was calculated in ArcGIS for both the distance from shore and the maximum bathymetric contours.

Probable Areal Range: *-3-1500m*

Depth Range: *0-3700m*
A potential oil wellhead blowout could occur at any depth at which oil and gas activities could occur; thus the depth range is set at 0-3,700m. Though some chemical components of oil spills may settle into water deeper than the actual blowout depth, that level of detail is not accounted for in this programmatic model, thus the maximum drill depth is used as the maximum affected depth.

Probable Depth Range: *0-1500m*

Impact Scale: *Large*

Impact Duration: *Moderate Term*

Oil Spills are defined as a Moderate-Term impact factor (Moderate term: a short-term event whose effects are relaxed over a short period of time (weeks to months) (pulse effect).

Current Level of Development: Current development is based on general public information regarding the current number of oil platforms/rigs in each planning area/broad OCS region.

D.2 RENEWABLE ENERGY IMPACT FACTORS

Three phases of impact producing factors are included in the Renewable Energy portion of the RESA (the following descriptions are drawn from the BOEM PEIS):

Exploration - Before a technology can be deemed feasible for commercial energy production, it must be tested in the OCS environment. Wave and ocean current technologies are less advanced than wind technologies, and proposals to test and demonstrate various forms of these technologies on the OCS can be expected in the next 5 to 7 years. A demonstration-scale test for these technologies would most likely involve the deployment of one or two devices per test—with or without an undersea transmission connection to the shore. The devices would be installed in the offshore environment, and depending on the size of the individual unit, they could be towed to their offshore locations or could be shipped by barge or special-purpose vessel. The demonstration units would also need to be fixed in place. Depending on the particular technology, this could be accomplished by using steel monopiles, multilegged support systems, concrete anchors, or slack mooring systems. In each case, the mooring technology used in the demonstration would likely be the type intended for commercial operations, although the demonstration may provide information that could be used to make design changes to improve the anchoring approach. The mooring technologies may require pile driving or other disturbances to the ocean bottom. Before installation of a technology, site-specific characterizations would need to be conducted to collect data on ocean-bottom characteristics and unidentified hazards (e.g., for mooring and undersea transmission), potential environmental impacts (e.g., to migratory bird routes, benthic habitats, and coastal sediment transport processes), potential archaeological impacts, and possible conflicting uses (e.g., radar interferences, commercial fishing, and U.S. Department of Defense training and operations). Integrated marine geophysical/ hydrographic surveys and geotechnical/sediment sampling programs provide data to assess and characterize existing seafloor and sub-seafloor conditions to select appropriate design, construction, and installation techniques. The objectives of these surveys and programs are generally to identify water depths, seafloor morphology and structural features, sub seafloor stratigraphy, and natural or man-made obstructions on or below the seafloor.

Development- Once exploration has confirmed the presence of a commercially viable location, the next phase of renewable energy development is the commercial scale sites. In general, the following activities would be conducted in the construction of an OCS energy conversion facility on the OCS.

Manufacturing of individual devices and/or components onshore. Components to be fabricated onshore include foundations or other anchoring devices (most likely made of steel, but concrete could also be used), turbines, rotors (most likely of composite materials), transformers, and transmission cables. Additional components for specific energy conversion technologies would include towers for WTGs (steel, manufactured in sections to be assembled offshore); buoys, anchoring devices, and other components for WECs; and possibly submersibles and underwater generators for ocean current technologies.

Transport of components to the port location from which they would be shipped to the OCS location. Transport would occur by truck and by marine vessel (for large components). Some of the WEC devices (e.g., point absorbers) would be built on the nearby shore, as components for these devices are typically available from U.S. suppliers. These devices can be built locally using standard construction techniques available in most shipyards. Some ocean current devices, on the other hand, are today made only in Europe, and these devices would need to be shipped overseas, or the technology would need to be licensed to North American companies for commercial production and transport to the port.

Port preparation. Existing ports may require expansion to accommodate the equipment (e.g., large cranes for offloading and reloading components). Construction work including dredging and dock expansion may be needed.

Installation of components offshore. Technicians to install the OCS systems would be transported by vessel to the OCS facility site; in some cases, helicopters may be used. Specific components to be installed would vary depending on the technology:

Anchoring devices. For the next 5 to 7 years, wind turbines can be expected to be mounted on towers supported by steel monopile foundations. Other OCS energy technologies (such as ocean current technologies that use rotors to generate electricity) may also use monopiles. Monopiles would likely be driven into the ocean floor by using vibratory hammers or other pile-driving equipment from a barge. Other technologies (point absorbers, attenuators, overtopping WEC devices) may use slack mooring configurations, and terminators may use asymmetric mooring arrangements, with the device supported on legs that connect the structure with the seabed. Scour protection
(e.g., rubble mounds, seagrass mattresses) may also be required.

Energy conversion devices. To minimize operations in harsh offshore environments, as much assembly of the turbines and other conversion devices as possible would occur onshore. For some technologies, the entire device may be built onshore and transported as a unit to the site; others would require additional assembly offshore. This would likely be done from a barge or special-purpose vessel with the capacity to handle large equipment. The remaining offshore assembly of individual devices could require less than a day (for some WTGs) to a week or more (for some WECs).

Transformers/service platforms. These would be assembled in a manner similar to the energy conversion devices, that is, as much assembly as possible would occur onshore, and offshore assembly and installation would be conducted from barges or other special purpose vessels.

Subsea cables. Subsea cable installation would include both medium-voltage cables within the OCS facility to collect the electricity generated from the individual devices and transmit it to the

transformer, and high-voltage cables for transmission from the transformer(s) to the shore. Special cable-laying vessels designed specifically for both transport and installation would likely be used if the cables were buried, and generally these cables would be buried using a jet-plow technique in the seafloor about 1 to 3 m (3 to 10 ft). This technique simultaneously lays and embeds submarine cable in one continuous trench. It is possible that in deep waters, where the cables would not interfere with other marine uses, the cables would not be buried. Additional precautions would be needed if it were deemed necessary to transmit the energy over rocky or seismically active areas.
Components of submarine cables that may result in environmental impacts include the type of insulation, number of conductors (e.g., single versus "three-core" cables), screening, sheathing (which, because it is often metallic, helps ground the cable and creates a moisture barrier), and armor. Armor is the overall jacket, to which corrosion protection is applied. Corrosion protection may include a biocide.

Operation- Routine operations of OCS energy conversion facilities generally would not require offshore personnel. The control and monitoring of devices and transformers would be carried out remotely using fiber-optic cables or other communication devices. However, periodic maintenance and inspection would be required. Wind turbines, for example, would be inspected and serviced about twice a year (to receive a change of oil, replenish lubrication, check fasteners, change filters, inspect major components, etc.); corrections of malfunctions would also be required. Together, such services may average about 1 wk/yr per turbine. (It should be noted that the wind facility would continue production during scheduled maintenance activities; only the unit undergoing maintenance would be shut down.) Technicians would be transported by relatively small boats to the turbine (or transformer) sites where they would either work directly on the turbine or transport components to the shore for repair and then return them. In poor weather conditions, the technicians may be transported via helicopter to the OCS location. reliability management, structural monitoring, and repair. Offshore systems may need to be returned periodically to shore for maintenance or replacement. Remote monitoring and supervisory controls are expected. To repair any of the submerged components (e.g., hose pumps, piston assembly, and check valves), a buoy would need to be floated into a horizontal position. This would require a crane to bring it into a horizontal position or the pumping of air into subsea compartments. The buoy can also be towed into a nearby port for major overhaul activities. The terminator WEC can be accessed by boat for regular maintenance. The operation and maintenance strategy for this type of device would be to conduct as many tasks as possible on the device itself and to remove the device only in case of critical structural failures. For attenuators, device maintenance would likely be conducted at a pier onshore. The device can be disconnected from its mooring and towed to a nearby port for maintenance overhauls; subsystems, such as power modules, can be lifted out with a crane and replaced.

Decommission- Decommissioning activities are not included in this analysis. This is due to the wide range of decommissioning activities which occur (explosive vs. non-explosive) and the uncertain timeframe in which decommissioning activities occur.

D.2.1 Impact Factor: Accidental Spills

Definition: Accidental Spills entail small oil and chemical spills not resulting from routine operations. Accidental spills may be associated with production accidents, transportation failures, and low-level releases from turbines (BOEM, 2012). Additionally, accidental spills include the release of solid waste materials such as plastic containers or construction materials.

Areal Range: *-3-200m*
Impact Areal Range minimum is assumed to be the shoreline (0 m) for all impact factors. This assumption is based in the potential that the two impacts (Oil and Gas and Renewable Energy) could potentially occur right up to the shoreline. No evidence has been presented to the contrary. The maximum areal range is based upon the maximum reported depth at which offshore wind development can/has occur(ed). Maximum depth at which renewable energy could occur based off of current wind turbine technology which allows development out to approximately 200 m depths (Dvorak et al. 2009). Tidal energy projects are not included due to their proximity to the shoreline (they do not fall under BOEM jurisdiction). Wave energy devices may be installed in a wide variety of depths but potential projects are often assessed out to the 60 m bathymetric contours (Bedard et al. 2005). Though some projects may eventually occur outside of the 200 m contour (the current maximum wind energy depth), those projects are a ways in the future and are therefore not included in this assessment. Therefore, the maximum distance from shore for renewable energy is set at 200 m as per wind energy. Impact areal range maximum (distance from shore) was calculated based on the distance from shore the maximum bathymetric contour occurs at for each geographic region (average). Worldwide bathymetry data was obtained through the NOAA ETOPO1 Global Relief Model, a global 1 arc-minute model that integrates both land topography and ocean bathymetry. The data, in the form of a float file, was imported into ArcGIS and the "Contour List" tool within the Spatial Analyst Toolbox Extension was used to extract a bathymetry contour of 200 m. Distances between the coastline and the contours were measured in each of the planning regions using the "Distance' tool. However, the contours are not entirely consistent within the planning regions, therefore these distances are mere averages.

Probable Areal Range: *0-50m*

Depth Range: *0-100m*
Accidental Spills are assumed to potentially occur at the surface or near-surface of the water column. A value of 100m depth is used to define the maximum depth at which this impact causing factor could occur.

Probable Depth Range: *0-50m*

Impact Scale: *Small*

Impact Duration: *Short-term*
Accidental Spills fall into the Short-Term category: a short-term event whose effects are relaxed almost immediately (minutes to days) (pulse effect).

Current Level of Development: There is no current large scale renewable energy development on the outer continental shelf of the United States. As such all current level of development is set as None.

D.2.2 Impact Factor: Artificial Light

Definition: Artificial Light refers to all light emanating from the exploration, construction and operation of offshore wind and wave renewable energy activities. Detrimental effects of artificial light may include increased chances of collision, skewed migratory pathways, and unnatural accumulation of species to non-preferable habitats.

Areal Range: *-3-200m*
Impact Areal Range minimum is assumed to be the shoreline (0 m) for all impact factors. This assumption is based in the potential that the two impacts (Oil and Gas and Renewable Energy) could potentially occur right up to the shoreline. No evidence has been presented to the contrary. The maximum areal range is based upon the maximum reported depth at which offshore wind development can/has occur(ed). Maximum depth at which renewable energy could occur based off of current wind turbine technology which allows development out to approximately 200 m depths (Dvorak et al. 2009). Tidal energy projects are not included due to their proximity to the shoreline (they do not fall under BOEM jurisdiction). Wave energy devices may be installed in a wide variety of depths but potential projects are often assessed out to the 60 m bathymetric contours (Bedard et al. 2005). Though some projects may eventually occur outside of the 200 m contour (the current maximum wind energy depth), those projects are a ways in the future and are therefore not included in this assessment.

Probable Areal Range: *5-50m*

Depth Range: *-150-5m*
Minimum depth range for Artificial Light represents the maximum height above the waterline at which artificial light may adversely affect biota. A height of 150 m has been selected; the largest wind turbine currently in construction is the Enercon E-126 with a hub height of 135 m. The distance traveled by artificial light may extend the visible effects of the artificial light to around 150m. The maximum depth of artificial light is given as 0 m. Complete light attenuation is assumed to occur at the water surface.

Probable Depth Range: *-150-5m*

Impact Scale: *Moderate*

Impact Duration: *Permanent*
Given the extremely long life span of wind turbines (approximately 30 years) and the persistent use of artificial light on the hub of each turbine; artificial light is designated as a permanent impact factor.

Current Level of Development: There is no current large scale renewable energy development on the outer continental shelf of the United States. As such all current level of development is set as None.

D.2.3 Impact Factor: Collisions with Above-Surface Structures

Definition: This impact factor is defined as the detrimental effects of above water surface structures on biota unaccustomed to the BOEM regulated activity structures on the outer continental shelf, resulting in collisions with said structures. In this instance, collisions refer almost exclusively to collisions of bird species with rotor blades and hubs of wind turbines.

Areal Range: *0-200m*
Impact Areal Range minimum is assumed to be the shoreline (0 m) for all impact factors. This assumption is based in the potential that the two impacts (Oil and Gas and Renewable Energy) could potentially occur right up to the shoreline. No evidence has been presented to the contrary. The maximum areal range is based upon the maximum reported depth at which offshore wind development can/has occur(ed). Maximum depth at which renewable energy could occur based off of current wind turbine technology which allows development out to approximately 200 m depths (Dvorak et al. 2009). Tidal energy projects are not included due to their proximity to the shoreline (they do not fall under BOEM jurisdiction). Wave energy devices may be installed in a wide variety of depths but potential projects are often assessed out to the 60 m bathymetric contours (Bedard et al. 2005). Though some projects may eventually occur outside of the 200 m contour (the current maximum wind energy depth), those projects are a ways in the future and are therefore not included in this assessment.

Probable Areal Range: *5-50m*

Depth Range: *-215-0m*
Minimum depth range for Collisions represents the maximum height above the waterline at which collisions may adversely affect biota. A height of 215 m has been selected; the largest wind turbine currently in construction is the Enercon E-126 with a hub height of 135 m and a rotor diameter of 127 m. No detrimental collision is assumed to occur below the water surface. However 0 m is used as the depth maximum in the case of accidental collisions with the tower structure.

Probable Depth Range: *-215-0m*

Impact Scale: *Site Specific*

Impact Duration: *Permanent*
Given the extremely long life span of wind turbines (approximately 30 years), Collisions are designated as a Permanent impact factor.

Current Level of Development: There is no current large scale renewable energy development on the outer continental shelf of the United States. As such all current level of development is set as None.

D.2.4 Impact Factor: Habitat Disturbance

Definition: Habitat disturbance refers to general benthic habitat disturbance and displacement due to infrastructure placement (including structure and pipelines).

Areal Range: *0-200m*
Impact Areal Range minimum is assumed to be the shoreline (0 m) for all impact factors. This assumption is based in the potential that the two impacts (Oil and Gas and Renewable Energy) could potentially occur right up to the shoreline. No evidence has been presented to the contrary. The maximum areal range is based upon the maximum reported depth at which offshore wind development can/has occur(ed). Maximum depth at which renewable energy could occur based off of current wind turbine technology which allows development out to approximately 200 m depths (Dvorak et al. 2009). Tidal energy projects are not included due to their proximity to the shoreline (they do not fall under BOEM jurisdiction). Wave energy devices may be installed in a wide variety of depths but potential projects are often assessed out to the 60 m bathymetric contours (Bedard et al. 2005). Though some projects may eventually occur outside of the 200 m contour (the current maximum wind energy depth), those projects are a ways in the future and are therefore not included in this assessment.

Probable Areal Range: *5-50m*

Depth Range: *0-200m*
Habitat disturbance may occur at any depth where renewable energy development occurs. This has been set at depth of 0m – 200m.

Probable Depth Range: *5-50m*

Impact Scale: *Site Specific*

Impact Duration: *Permanent*
Given the extremely long life span of wind turbines (approximately 30 years) Habitat Disturbance is designated as a permanent impact factor.

Current Level of Development: There is no current large scale renewable energy development on the outer continental shelf of the United States. As such all current level of development is set as None.

D.2.5 Impact Factor: Sound/Noise

Definition: The Sound/Noise impact factor refers to the artificial sound and noise created by renewable energy ship and siting exploration (including seismic surveys), construction, and operation. The main drivers of sound and noise include: seismic surveys, ship traffic noise, construction of offshore facilities and pipelines, and site operation.

Areal Range: *-3-200m*
Impact Areal Range minimum is assumed to be the shoreline (0 m) for all impact factors. This assumption is based in the potential that the two impacts (Oil and Gas and Renewable Energy) could potentially occur right up to the shoreline. No evidence has been presented to the contrary. The maximum areal range is based upon the maximum reported depth at which offshore wind development can/has occur(ed). Maximum depth at which renewable energy could occur based

off of current wind turbine technology which allows development out to approximately 200 m depths (Dvorak et al. 2009). Tidal energy projects are not included due to their proximity to the shoreline (they do not fall under BOEM jurisdiction). Wave energy devices may be installed in a wide variety of depths but potential projects are often assessed out to the 60 m bathymetric contours (Bedard et al. 2005). Though some projects may eventually occur outside of the 200m contour (the current maximum wind energy depth), those projects are a ways in the future and are therefore not included in this assessment.

Probable Areal Range: *5-50m*

Depth Range: *-150-100m*
The depth range of the Sound/Noise impact factor is deemed to be from -150 - 100m. Though construction of offshore renewable energy will result in artificially elevated sound at depths greater than this, the source levels from drilling are relatively low (154 dB and below, as cited by Greene [1986] in Richardson et al. [1995]), below the level B (behavioral) harassment threshold of 160 dB (set by NMFS). Thus only surface related sound/noise is considered in this analysis. Additionally, the elevated sound from rotors is accounted for in the above water portion of the depth range.

Probable Depth Range: *-150-50m*

Impact Scale: *Moderate*

Impact Duration: *Chronic*
Though two types of sound/noise are being considered in this assessment (construction noise, operation/rotor noise, the greater frequency of these two is used for impact characterization. Impact frequency is considered to be chronic: a sustained, long-term, or chronic event whose effects are not relaxed (press effect).

Current Level of Development: There is no current large scale renewable energy development on the outer continental shelf of the United States. As such all current level of development is set as None.

D.2.6 Impact Factor: Vessel Strikes

Definition: Service vessel traffic during construction and operation of renewable energy projects is forecast to be extremely high. There have been documented reports of cetaceans being struck by ships in the oceans throughout the world (Laist et al. 2001; Jensen and Silber 2004; Glass et al. 2008). Analyses by Vanderlaan and Taggart (2007) provides evidence that as vessel speeds fall below 15 knots, there is a substantial decrease in the probability of a vessel strike to prove lethal to a large whale. Collisions with vessels greater than 80 m (260 ft) in length are usually either lethal or result in severe injuries (Laist et al. 2001). In addition, a majority of ship strikes seemed to occur over or near the continental shelf. Collisions with vessels can cause major wounds on marine mammals and/or be fatal. Debilitating injuries may have negative effects on a population through impairment of reproductive output (MMS 2003).

Areal Range: *0-200m*

Probable Areal Range: *0-50m*

Depth Range: *0-10m*

Probable Depth Range: *0-10m*

Impact Scale: *Moderate*

Impact Duration: *Chronic*

Current Level of Development: There is no current large scale renewable energy development on the outer continental shelf of the United States. As such all current level of development is set as None.

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APPENDIX E: SHORELINE HABITAT DATA USED IN THE RESA

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Table E-1: States for Which ESI Data were Obtained for Practical Application of RESA Method

State	Section of State	Data Type	
		Shapefile	Geodatabase
Alabama	Statewide	x	
Alaska	Aleutian Islands	x	
	Bristol Bay		x
	Cook Inlet/Kenai Peninsula	x	
	Kodiak		x
	North Slope	x	
	Northwest Arctic		x
	Prince William Sound		x
	Southeast Alaska		x
	Western Alaska		x
California	Central		x
	Northern		x
	San Francisco		x
	Southern		x
Connecticut[1]	Statewide		x
Delaware[2]	Statewide		x
Florida	Statewide		x
Georgia	Statewide		x
Louisiana	Statewide	x	
Maine*	Statewide		x
Maryland	Statewide		x
Massachusetts	Statewide		x
Mississippi	Statewide	x	
New Hampshire	Statewide		x
New Jersey[1,2]	Statewide		x
New York[1]	Partial State		x
New York	Hudson River		x
	Long Island		x
North Carolina	Statewide		x
Oregon	Columbia River		x
	Oregon		x
Pennsylvania[2]	Statewide		x
Rhode Island[1]	Statewide		x
South Carolina	Statewide		x
Texas	Statewide		x
Virginia	Statewide		x
Washington	Puget Sound		x
	Washington		x

[1] Geodatabase contains data for Connecticut, part of New Jersey, part of New York and Rhode Island

[2] Geodatabase contains data for Delaware, New Jersey and Pennsylvania

* Maine shoreline data provided as Environmental Vulnerability Index (EVI) geodatabase

E.1 PROCEDURE FOR ESI DATA PROCESSING FOR APPLICATION IN THE RESA MODEL

For most of the states, the data formats were identical or very similar. However, some datasets were either more recent, more complete or based on a different attribute table structure than the majority of the data. Where states had incomplete data sets, the data sets were still used since they were the best available data at the time of the evaluation.

Within each shapefile, some filtering was necessary to be able to compare appropriate portions of the shoreline in the analysis. Segments of line that were designated as riverine were not suitable for this analysis, and were eliminated from the datasets so that all remaining line segments had a designation of ENVIR (Physiographic Region) equal to "E" (Estuarine). For some states such as Texas, datasets did not have this designation and all data were considered for the analysis.

For the state of Maine, a unique type of shoreline sensitivity data was available called Environmental Vulnerability Index (EVI) data. This is the only dataset presently available from NOAA; however the spatial format of the data differs slightly from the ESI data. The same ten classifications used in the ESI data were given in the EVI data in polygon form, rather than along segments of the coastline. Values from these polygons were assigned to the coastline provided with the EVI dataset where ever possible. In areas where no polygon overlapped or contacted the shoreline, that length of shoreline was not considered in this scoring process.

Once the riverine segments of line were removed, the lines within each state dataset were dissolved together based on the field "MOSTSENSIT" so that only one feature existed for each unique value within this field. A new field was added to the attribute table and labeled "ESI_Class" (ESI Classification). All features were calculated so that "ESI_Class" reflected only the numeric values in "MOSTSENSIT". For example, any features with a "MOSTSENSIT" value of "10a" were calculated so that "ESI_Class" was equal to "10."

For each broad OCS region, the individual states' datasets were merged into a single shapefile. State datasets were clipped at the boundary of the broad OCS region and only the portions within that region were used in the merged dataset. Once a single shapefile existed for each region, the lines within each state dataset were dissolved together based on the field "ESI_Class," so that a single feature existed for each unique value within this field.

Broad OCS regions generally span two or three of the different coordinate projection systems that were used to calculate the lengths of the linear features. The extents of these projections were used to clip each broad OCS region ESI shapefile into smaller shapefiles, and each of the smaller shapefiles were projected into the appropriate coordinate system. For example, the Eastern Gulf of Mexico was clipped to two coordinate projection systems: UTM 16N and UTM 17N. These projected sections of shoreline were used to make more accurate length calculations for each ESI Classification within a broad OCS region. The lengths for each ESI Classification within a broad OCS region were then summed and used in calculating the final shoreline habitat score.

Tables E-2 through E-10 present the results of the ESI calculations by broad OCS region. For each ESI Class within the region, the total miles of shoreline designated as that ESI Class are given under the heading "Total Miles." In the final row of each table under this column, the total miles of shoreline in the broad OCS region is given. When the "Total Miles" for each ESI Class was calculated as a percent of the "Total Miles" for the broad OCS region, the result is shown in the "Percent of Total" column. The sum of percentages for all ESI Classes is always 100. To obtain the results for each ESI Class under the column "Score," the "Percent of Total" for that ESI Class was multiplied by the numeric "ESI Class" value. Finally, the scores for the individual ESI Classes were summed and then divided by 100 in order to obtain a broad OCS region score within a scale of 1 to 10 (given in the final row of the "Score" column of each table). Regions with higher numbers (closer to 10) indicate relatively more sensitive shorelines than regions with lower numbers (closer to 1). The scores for each broad OCS region and the ranking of the nine regions from most to least sensitive are listed in Table E-11.

Table E-2: Percentage of Shoreline per ESI Classification for the Northeast Continental Shelf Broad OCS Region

NECS			
ESI Class	**Total Miles**	**Percent of Total**	**Score**
1	868.59	2.48	2.48
2	137.55	0.39	0.79
3	752.51	2.15	6.46
4	1,324.72	3.79	15.15
5	831.43	2.38	11.89
6	1,174.87	3.36	20.16
7	607.13	1.74	12.15
8	4,209.47	12.04	96.31
9	2,656.77	7.60	68.38
10	22,404.53	64.07	640.72
Total	**34,967.57**	**100**	**8.74**

Table E-3: Percentage of Shoreline per ESI Classification for the Southeast U.S. Continental Shelf Broad OCS Region

SECS			
ESI Class	**Total Miles**	**Percent of Total**	**Score**
1	255.19	1.11	1.11
2	9.62	0.04	0.08
3	891.22	3.87	11.60
4	496.94	2.16	8.62
2	55.30	0.24	0.48
6	303.25	1.32	7.89
7	130.43	0.57	3.96
8	1,773.22	7.69	61.52
9	772.74	3.35	30.16
10	18,369.82	79.67	796.69
Total	**23,057.74**	**100**	**9.22**

Table E-4: Percentage of Shoreline per ESI Classification for the Eastern Gulf of Mexico Broad OCS Region

EGOM			
ESI Class	Total Miles	Percent of Total	Score
1	114.17	0.70	0.70
2	1.84	0.01	0.02
3	663.27	4.06	12.17
4	159.34	0.97	3.90
5	77.67	0.48	2.38
6	145.80	0.89	5.35
7	244.00	1.49	10.45
8	2,306.21	14.11	112.88
9	123.54	0.76	6.80
10	12,507.98	76.53	765.30
Total	**16,343.84**	**100**	**9.20**

Table E-5: Percentage of Shoreline per ESI Classification for the Western Gulf of Mexico Broad OCS Region

WGOM			
ESI Class	Total Miles	Percent of Total	Score
1	216.52	1.94	1.94
2	407.29	3.65	7.30
3	824.83	7.39	22.18
4	7.92	0.07	0.28
5	268.32	2.41	12.03
6	422.40	3.79	22.72
7	224.24	2.01	14.07
8	1,396.97	12.52	100.19
9	429.00	3.85	34.61
10	6,956.91	62.37	623.69
Total	**11,154.41**	**100**	**8.39**

Table E-6: Percentage of Shoreline per ESI Classification for the California Current Broad OCS Region

CALC			
ESI Class	**Total Miles**	**Percent of Total**	**Score**
1	297.31	7.54	7.54
2	312.55	7.92	15.85
3	538.10	13.64	40.93
4	152.77	3.87	15.50
5	176.60	4.48	22.39
6	453.52	11.50	69.00
7	41.12	1.04	7.30
8	336.30	8.53	68.22
9	306.73	7.78	70.00
10	1,328.84	33.69	336.94
Total	**3,943.83**	**100**	**6.54**

Table E-7: Percentage of Shoreline per ESI Classification for the Washington/Oregon Broad OCS Region

WAOR			
ESI Class	**Total Miles**	**Percent of Total**	**Score**
1	275.47	5.44	5.44
2	100.84	1.99	3.98
3	314.89	6.21	18.64
4	154.91	3.06	12.23
5	913.42	18.03	90.14
6	469.62	9.27	55.61
7	405.27	8.00	55.99
8	370.14	7.30	58.44
9	427.32	8.43	75.90
10	1,635.03	32.27	322.69
Total	**5,066.91**	**100**	**6.99**

Table E-8: Percentage of Shoreline per ESI Classification for the Gulf of Alaska Broad OCS Region

GOAK			
ESI Class	**Total Miles**	**Percent of Total**	**Score**
1	3,161.34	12.62	12.62
2	2,665.46	10.64	21.29
3	429.75	1.72	5.15
4	218.45	0.87	3.49
5	2,811.89	11.23	56.14
6	5,321.94	21.25	127.50
7	2,243.71	8.96	62.71
8	4,642.57	18.54	148.30
9	685.15	2.74	24.62
10	2,864.24	11.44	114.37
Total	**25,044.52**	**100**	**5.76**

Table E-9: Percentage of Shoreline per ESI Classification for the East Bering Sea Broad OCS Region

EBSE			
ESI Class	**Total Miles**	**Percent of Total**	**Score**
1	1,544.49	14.00	14.00
2	1,528.25	13.85	27.70
3	333.36	3.02	9.06
4	446.38	4.05	16.18
5	1,163.60	10.55	52.73
6	694.93	6.30	37.79
7	523.56	4.75	33.22
8	676.36	6.13	49.04
9	651.39	5.90	53.13
10	3,470.96	31.46	314.59
Total	**11,033.27**	**100**	**6.07**

Table E-10: Percentage of Shoreline per ESI Classification for the Chukchi/Beaufort Sea Broad OCS Region

CBSE			
ESI Class	**Total Miles**	**Percent of Total**	**Score**
1	44.94	0.74	0.74
2	49.87	0.82	1.65
3	983.05	16.22	48.67
4	81.58	1.35	5.39
5	1,056.20	17.43	87.15
6	109.01	1.80	10.79
7	305.22	5.04	35.26
8	410.73	6.78	54.22
9	753.41	12.43	111.89
10	2,265.94	37.39	373.92
Total	**6,059.96**	**100**	**7.30**

Table E-11: Shoreline Sensitivity Scores and Rankings by Broad OCS Region

Broad OCS Region	Shoreline Sensitivity Score	Rank
SECS	9.22	1
EGOM	9.20	2
NECS	8.74	3
WGOM	8.39	4
CBSE	7.30	5
WAOR	6.99	6
CALC	6.54	7
EBSE	6.07	8
GOAK	5.76	9

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APPENDIX F: SPECIES AND HABITAT SCORES FROM THE RELATIVE ENVIRONMENTAL SENSITIVITY ANALYSIS

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Table F-1: Individual Species Scores for Each Broad OCS Planning Area, Totaled for BOEM Activities (a blank score indicates that species was not selected for analysis in that Broad OCS Planning Area based on criteria in Section 2.1.5)

Selected Species		Atlantic		Gulf of Mexico		Pacific		Alaska			Mean
		NECS	SECS	E	W	CALC	WAOR	CBS	EBS	GOAK	
Birds	Glaucous-winged Gull	.	.	.	.	.	15	.	26	27	22.7
	Double-crested Cormorant	22	22	22	23	.	.	.	.	.	22.3
	Spectacled Eider	.	.	.	.	.	.	22	.	.	22.0
	Pigeon Guillemot	.	.	.	.	.	.	.	21	.	21.0
	Western Gull	.	.	.	.	21	.	.	.	.	21.0
	Marbled Murrelet	.	.	.	.	21	21	.	.	20	20.7
	Piping Plover	.	.	20	20	.	.	.	.	.	20.0
	Steller's Eider	.	.	.	.	.	.	11	23	14	16.0
	Glaucous Gull	.	.	.	.	.	.	13	.	.	13.0
	Snowy Plover	.	.	.	.	13	13	.	.	.	13.0
	Wood Stork	.	10	13	.	.	.	.	.	.	11.5
	Red-necked Phalarope	.	.	.	.	.	.	8	.	.	8.0
	Magnificent Frigatebird	.	.	6	7	.	.	.	.	.	6.5
	Whooping Crane	.	.	.	5	.	.	.	.	.	5.0
	Short-tailed Albatross	.	.	.	.	.	.	.	4	5	4.5
	Sooty Shearwater	.	.	.	.	4	5	.	.	.	4.5
	Roseate Tern	3	3	.	.	.	.	.	.	.	3.0
	Wilson's Storm-Petrel	2	3	.	.	.	.	.	.	.	2.5
	Red Knot	2	.	.	.	.	.	.	.	.	2.0
Fish	Atlantic sturgeon	32	32	.	.	.	.	.	.	.	32.0
	Red snapper	.	.	.	23	.	.	.	.	.	23.0
	Smalltooth sawfish	.	.	22	.	.	.	.	.	.	22.0
	Steelhead trout	.	.	.	.	21	.	.	.	.	21.0

Selected Species		Atlantic		Gulf of Mexico		Pacific		Alaska			Mean
		NECS	SECS	E	W	CALC	WAOR	CBS	EBS	GOA K	
	Vermillion snapper	.	21	.	.	.	.	.	.	.	21.0
	Atlantic croaker	.	.	.	18	.	.	.	.	.	18.0
	Bocaccio	.	.	.	.	.	17	.	.	.	17.0
	Red grouper	.	.	17	.	.	.	.	.	.	17.0
	Gulf menhaden	.	.	.	16	.	.	.	.	.	16.0
	Walleye pollock	.	.	.	.	.	.	.	17	14	15.5
	Atlantic herring	15	.	.	.	.	.	.	.	.	15.0
	Atlantic mackerel	13	.	.	.	.	.	.	.	.	13.0
	Atka mackerel	.	.	.	.	.	.	.	12	.	12.0
	Gulf sturgeon	.	.	.	12	.	.	.	.	.	12.0
	Northern anchovy	.	.	.	.	12	.	.	.	.	12.0
	Pink salmon	.	.	.	.	.	.	.	10	11	10.5
	Menhaden	10	.	.	.	.	.	.	.	.	10.0
	Arctic cod	.	.	.	.	.	.	8	.	.	8.0
	Arrowtooth flounder	.	.	.	.	.	.	.	.	8	8.0
	Bay anchovy	.	.	8	.	.	.	.	.	.	8.0
	Striped mullet	.	7	8	.	.	.	.	.	.	7.5
	Pacific herring	.	.	.	.	.	.	.	.	7	7.0
	Spanish mackerel	.	6	.	.	.	.	.	.	.	6.0
	Arctic cisco	.	.	.	.	.	.	4	.	.	4.0
	Dolly varden	.	.	.	.	.	.	4	.	.	4.0
	Pacific sardine	.	.	.	.	3	3	.	.	.	3.0
	Chub mackerel	.	.	.	.	3	.	.	.	.	3.0
	Albacore tuna	.	.	.	.	.	2	.	.	.	2.0
	Pacific hake (whiting)	.	.	.	.	.	2	.	.	.	2.0
Invertebrates	Baltic macoma clam	.	.	.	.	.	.	25	25	26	25.3
	American oyster	.	20	22	23	.	.	.	.	.	21.7
	Pacific oyster	.	.	.	.	.	20	.	.	.	20.0

Selected Species		Atlantic		Gulf of Mexico		Pacific		Alaska			Mean
		NECS	SECS	E	W	CALC	WAOR	CBS	EBS	GOA K	
	Red sea urchin	.	.	.	.	20	19	.	.	.	19.5
	Surf clam	19	.	.	.	.	.	.	.	.	19.0
	Blue crab	17	17	17	18	.	.	.	.	.	17.3
	Dungeness crab	.	.	.	.	17	16	.	.	.	16.5
	Blue king crab	.	.	.	.	.	.	16	.	.	16.0
	White shrimp	.	15	.	15	.	.	.	.	.	15.0
	Snow crab	.	.	.	.	.	.	13	16	.	14.5
	Florida stone crab	.	.	14	.	.	.	.	.	.	14.0
	Brown shrimp	.	13	.	13	.	.	.	.	.	13.0
	Euphausiid (*T. inermis*)	.	.	.	.	.	.	13	13	13	13.0
	Longfin inshore squid	13	.	.	.	.	.	.	.	.	13.0
	Pink shrimp	.	.	13	.	.	.	.	.	.	13.0
	Tanner crab	.	.	.	.	.	.	.	.	13	13.0
	American lobster	12	.	.	.	.	.	.	.	.	12.0
	Golden king crab	.	.	.	.	.	.	.	12	12	12.0
	Ocean shrimp	.	.	.	.	12	12	.	.	.	12.0
	California market squid	.	.	.	.	11	.	.	.	.	11.0
Marine Mammals and Turtles	Florida manatee	.	46	46	.	.	.	.	.	.	46.0
	Atlantic spotted dolphin	.	31	.	.	.	.	.	.	.	31.0
	Loggerhead turtle	.	27	.	.	.	.	.	.	.	27.0
	Polar bear	.	.	.	.	.	.	25	.	.	25.0
	Hawksbill turtle	.	.	20	20	.	.	.	.	.	20.0
	North Pacific Right Whale	.	.	.	.	.	.	.	19	19	19.0
	Kemp's turtle	.	.	.	19	.	.	.	.	.	19.0
	Fin Whale	26	.	.	.	11	.	.	.	.	18.5
	North Atlantic Right Whale	30	7	.	.	.	.	.	.	.	18.5
	Green turtle	.	14	20	20	.	.	.	.	.	18.0
	Ringed Seal	.	.	.	.	.	.	17	.	.	17.0

Selected Species	Atlantic		Gulf of Mexico		Pacific		Alaska			Mean
	NECS	SECS	E	W	CALC	WAOR	CBS	EBS	GOAK	
Short-beaked common dolphin	18	.	.	.	12	.	.	.	.	15.0
Southern resident killer whale	.	.	.	.	.	14	.	.	.	14.0
Sperm whale	.	.	14	15	11	12	.	15	15	13.7
Pantropical spotted dolphin	.	.	13	14	.	.	.	.	.	13.5
Dall's porpoise	.	.	.	.	.	12	.	.	.	12.0
Leatherback turtle	9	.	.	.	13	14	.	.	.	12.0
Humpback Whale	26	.	.	.	9	6	.	8	9	11.6
Bowhead Whale	.	.	.	.	.	.	10	.	.	10.0
Beluga Whale	.	.	.	.	.	.	9	.	.	9.0
Steller sea lion	.	.	.	.	.	.	.	8	10	9.0
Northern fur seal	.	.	.	.	.	.	.	8	4	6.0
Pacific Walrus	.	.	.	.	.	.	4	.	.	4.0
TOTAL	268	293	297	280	212	202	199	237	225	245.9

Table F-2: Individual Habitat Scores for Each Broad OCS Region Totaled for BOEM Activities (a blank score indicates that habitat was not selected for analysis in that Broad OCS Planning Area based on criteria in Section 2.1.6)

SELECTED HABITATS[1]		Atlantic		Gulf of Mexico		Pacific		Alaska			Mean
		NECS	SECS	E	W	CALC	WAOR	CBS	EBS	GOAK	
M/B	Sabellariid Worm Reef	.	19	.	.	.	.	.	.	.	19.0
M/B	Live Hard Bottoms	.	.	16	.	.	.	.	.	.	16.0
M/B	Nearshore Fine Unconsolidated Substrate (FUS)	.	.	.	.	13	13	13	14	16	13.8
E/P	Open Water	12	16	14	12	11	15	.	.	.	13.3
M/B	Submerged Aquatic Vegetation	.	.	13	.	.	.	.	.	.	13.0
M/P	Algal Rafts (*Sargassum*)	.	15	10	.	.	.	.	.	.	12.5
E/B	Aquatic Vascular Vegetation	18	18	.	15	7	7	.	9	9	11.9
E/B	Mollusk Reef	.	.	10	.	.	.	.	.	.	10.0
M/B	Shallow/Mesophotic Coral	.	10	.	.	.	.	.	.	.	10.0
M/P	Surface/Photic Zone	9	.	.	10	.	.	.	.	.	9.5
E/P	Coastal Band	.	.	.	.	.	.	7	10	10	9.0
M/B	Fine Unconsolidated Substrate (FUS)	2	2	.	17	.	.	.	.	.	7.0
E/B	Benthic Macroalgae	.	.	.	.	.	.	7	.	.	7.0
M/P	Algal Rafts (Kelp)	.	.	.	.	6	6	.	.	6	6.0
M/B	Submarine Canyon	3	.	.	.	9	.	.	.	.	6.0
M/B	Cobble/Rock	.	.	.	.	.	.	.	.	5	5.0
M/B	Shelf Break	.	.	.	.	.	.	.	5	.	5.0
M/B	Bank	4	.	.	5	.	.	.	.	.	4.5
M/P	Pack Ice	.	.	.	.	.	.	2	7	.	4.5
M/B	Seep	.	.	4	3	.	.	.	.	.	3.5
M/B	Boulder/Rock	.	.	.	.	.	1	5	.	.	3.0
M/B	Offshore FUS	.	.	.	.	.	.	3	.	.	3.0
M/B	Deep/Coldwater Coral	4	4	2	4	2	2	2	2	2	2.7
M/B	Ridge/Rock	.	.	.	.	.	.	.	1	.	1.0
M/B	Seamounts	.	.	.	.	0	0	.	.	0	0
TOTAL		50	84	69	66	50	45	38	48	49	498

[1]M= marine; E= estuarine; B=benthic; P =pelagic; FUS=fine unconsolidated substrate

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